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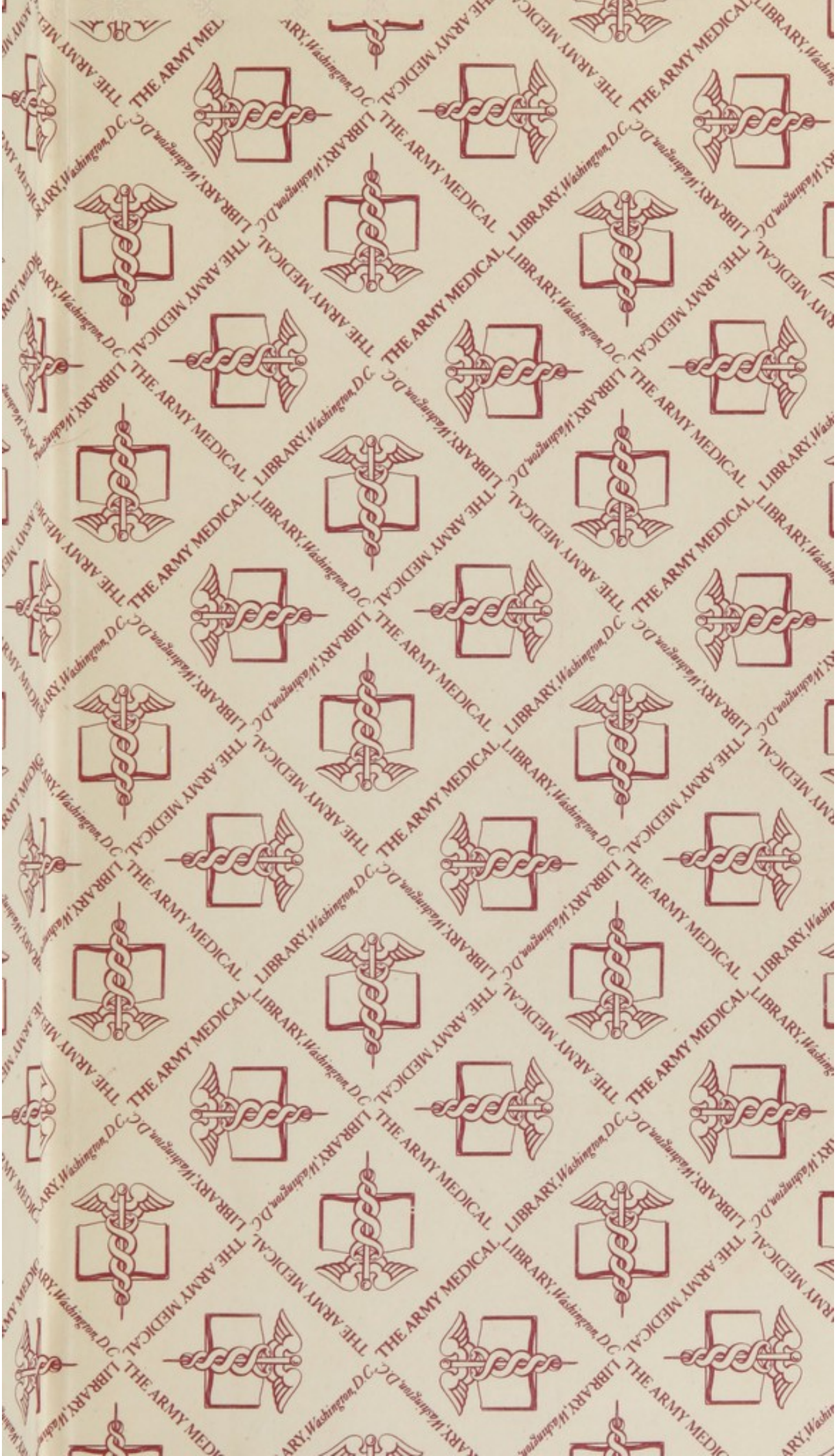
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FIRST LINES

OF

PHYSIOLOGY;

DESIGNED FOR THE USE OF

STUDENTS OF MEDICINE.

BY DANIEL OLIVER, M. D.

Professor of the Theory and Practice of Physic, &c. in Dartmouth College.

Multa esse constat in corpore, quorum vim rationemque perspicere nemo, nisi qui fecit, potest.....*Lactant. de opific. Dei.*

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PREFACE.

The following work had its origin in a request made to the author by the Medical Class of Dartmouth College, of the year 1833, that he would publish his Lectures on Physiology. He consented to take the subject into consideration, and if, upon a careful revision of his lectures, he should be able to satisfy himself, that they were, in any degree, worthy of the public eye, to comply with the wishes of his young friends. His final determination on the subject may be gathered without difficulty, from the appearance of the present work.

Whether he has acted wisely in presenting himself to the public, in the capacity of an author, on a subject preoccupied by numerous respectable, and some celebrated names, is a question which he will not venture to decide; but will only suggest, that the work, being designed for students, makes no pretensions to originality, or novelty, but is wholly derived from the copious sources of physiological knowledge, which have fertilized this department of science, and, from the nature of the case, can possess no higher merit than that of arrangement and correctness. But, with regard to the latter point, it is well known, that there are many questions, on which physiologists are by no means agreed; and that what one holds to be sound

doctrine, may be regarded as heretical by another; and that, of course, it is impossible for any system of opinions to obtain universal approbation. On such questions, the author has exercised the common privilege of being guided by his own judgment, after carefully weighing the authorities and the evidence on opposite sides of the disputed points.

In the collection of his materials, he has consulted all the works on the subject, which were accessible to him; but the authors to whom he is principally indebted are the following; viz. Adelon, Bourdon, Lepelletier, Magendie, Broussais, Mayo, Rudolphi,* Berthold,† Martini,‡ Jacopi,§ Tiedemann, and Tiedemann and Gmelin, and the authors of the admirable articles on Physiology, in the Dictionaire de Medicine. From most of these sources he has drawn largely, and, in many instances, without particular acknowledgment, which, in an elementary book, designed for students, appeared to be unnecessary.

Some apology may be thought necessary for the chapter on animal magnetism. This, he trusts, may be found in the attention, which this subject has recently attracted, chiefly in consequence of the publication of the Report of the Committee of the French Royal Academy, appointed to investigate the subject of animal magnetism, read before the Academy on the 21st and the 28th of June, 1831, and the extraordinary narrative of Jane Rider. The report mentioned above, signed by several distinguished French physi-

* Grundriss der Physiologie, Berlin, 1818.

† Lehrbuch der Physiologie, Göttingen, 1829.

‡ Elementa Physiologiæ, Taurini, 1828.

§ Elementi di Fisiologia e Notomia Comparativa, Livorno, 1823.

cians, the author regards as sufficient of itself to justify the insertion of a chapter on the subject; and the history of Jane Rider's somnambulism, contains several authentic facts, almost as incredible as the *mirabilia* of animal magnetism.

The Academy of Berlin, we are informed, in 1818, proposed a prize on this subject; and an ordinance of the Prussian government of 1817, prohibits the practice of magnetism to all but licensed physicians. In Russia and Denmark similar regulations have been adopted. Many eminent physicians of France and Germany have become converts to Mesmerism; and Hahnemann remarks, that none but madmen can entertain a doubt of its curative powers. The author expresses no opinion of his own upon the subject, but would merely remark, that a doctrine embraced by such men as Rostan, Georget, Guersent, Itard, Hufeland, and many other distinguished names, ought not to be rejected with contempt, and without examination, as a tissue of the grossest charlatanism and fraud.

In conclusion, the author, though aware of numerous imperfections in his book, ventures to express his hope, that it may not be found wholly unworthy of the attention of the profession, especially of its younger members, and of students, for whose use it is exclusively designed.

ERRATA.

The distance of the author's residence from the press, has given occasion to several errors to creep into the text. The reader is requested to correct the following, as affecting the sense. The others, consisting of literal errors, and obvious at the first glance, it was thought unnecessary to notice particularly.

Page 144, line 21—from top, dele, *owing*.
156, " 22—for *riveted*, lege, *united*.
160, " 24—for *thin*, l. *their*.
211, " 23—for *settled*, l. *fitted*.
238, " 10—for *to*, l. *depends on*.
254, " 9—for *for instance, as*, l. *as, for instance*.
266, " 21—insert *fluid*, after *gastric*.
301, " 19—for *Lown*, l. *Lower*.
310, " 28—for *thin*, l. *their*.
312, " 21—for *purgations*, l. *purgatives*.
" " 25—for *appearance*, l. *disappearance*.
321, " 32—for *muriate*, l. *minute*.
329, " 39—for *the*, l. *other*.
353, " 4—for *dogs*, read *days*.
361, " 12—for *cholestine*, l. *cholesterine*.
428, " 2—for *then*, l. *thus*.
432, " 41—for *five hundred*, l. *fifteen hundred*.
508, " 21—for *the magnetic sleep then*, l. *in magnetic sleep, there*.
509, " 10—insert *as*, after *necessary*.
" " 11—for *something*, l. *sometimes*.

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FIRST LINES OF PHYSIOLOGY.

CHAPTER I.

Definition.

PHYSIOLOGY is the science of life, or of the phenomena of living bodies; or it may be defined the science of organization; this term being used to express the living or active organization, and not being separable from the idea of life.

In contemplating the vast number of bodies, which present themselves to our notice, we perceive that they may all be referred to two great classes, viz: the organic, and the inorganic; distinguished from each other by certain striking properties, and each embracing an immense number of subdivisions, or subordinate classes. In each of these two great departments of nature, we observe two objects or elements essential to the class of beings we are considering; one, *a corporeal mass;* the other, *certain general properties* belonging to it; or, a *material* and a *dynamic* element; and these two are inseparably blended together, or only separable by an act of thought. We no where find matter divested of physical properties, and it is only by mental abstraction that we can conceive of it, as existing without them. For any thing we know, the property of attraction may be as essential to matter, as the corporeal mass which it presents to our senses. Attraction or gravitation, as isolated from matter, we know is nothing but an abstraction of our minds, and probably a corporeal mass, isolated from the dy-

namic element of matter, that is, from its physical or chemical properties, is no less so.

The same is true of organized matter. It consists of two elements, a corporeal mass, and certain properties inseparably blended together. These properties, which in their aggregate we term *life*, we can separate in thought from the sensible mass, with which they are united, but they cannot be separated in reality from it. When we speak of *life* or *vital properties*, we speak of mere mental abstractions, and we should never forget that this is the case, or we may be led into errors and absurdities in reasoning on the subject.

It may perhaps be supposed that, though life cannot exist without organization, yet the latter may exist separate from life, because we find by experience that all the external and sensible characters of organization, remain some time after the extinction of life. Yet, beyond all doubt, death is always accompanied with some essential change in the organization, though it may not be possible for us, in all cases, to determine what this is. In most instances, the lesions of the organization which occasion death, are obvious on dissection; and that they are not so in all, is probably owing to the fact, that science has never yet been able to penetrate into, and unravel the deeper mysteries of the organization, which constitute the immediate and essential condition of life.

The powers or forces, which are connected with inorganic matter are of two kinds, mechanical and chemical; and all matter, without exception, so far as our knowledge of it extends, is subject to the influence of these forces. The changes which take place in the physical world, and the motions and transformations of lifeless matter, which constitute these changes, are the results of the operation of these forces.

In addition to these two, organized matter is endued with another kind of force, which may be termed *organic*, or *vital*, and which is of a higher order than the two former. It exists in connection with the mechanical and chemical forces, for wherever it is

found, they are present likewise. It cannot exist without them, though they may exist without it. But wherever the organic force exists, it modifies, in a greater or less degree, the mere physical forces of matter, and sometimes appears almost to subvert them; but, as soon as the organic power has ceased to operate, the two former immediately resume their empire, and soon bring back the organized mass within the domain of inorganic nature.

CHAPTER II.

Comparison between Organic and Inorganic Matter.

A striking difference exists between the structure and general properties of organic and inorganic matter. The structure or material composition of organized bodies, is so peculiar and specific, as to form a remarkable contrast with that of inorganic matter. Their other characteristics are no less peculiar and distinguishing. The most important differences between these two classes of substances, will be briefly noticed.

1. An organized body always possesses a certain determinate form, peculiar to the species to which it belongs. Every species has its own type, and this is so peculiar, that the systematic place of every plant and every animal in existence, might be determined by the manner in which it occupies space, or, in other words, by its external shape. Mineral substances, on the contrary, never possess a fixed and invariable form, though in a state of crystallization, they frequently present forms of great regularity.

2. All organized bodies, plants as well as animals, are distinguished by rounded forms, which approach the spherical, oval, or cylindrical, and sometimes are branching and articulated. They scarcely ever present straight lines, or plane surfaces, or sharp angles or ridges, but are almost always bounded by curved or undulating lines, and by concave or convex surfaces. The forms of mineral substances, on the contrary, are bounded by plane surfaces, and straight lines, irregularly broken by sharp angles.

3. The volume of organized bodies is no less determined than their form. Every species of animal and vegetable, has its own proper size, to which, with accidental exceptions, every full grown individual belonging to it, conforms. But there are no fixed limits to the volume of mineral substances. They may be either great or small, according to the quantity of matter they contain, yet be absolutely identical in their nature or properties. The smallest fragment of a mineral substance has all the properties of the mass from which it was taken.

4. Upon examining organized bodies with a microscope, they are found to contain minute particles of matter of a globular or oval, and sometimes flattened shape. The fluid, as well as the solid parts, both of animals and plants, abound in these minute globules. Some of the lowest classes of the animal world, as the infusory *animalcula*, and the *polypus*, as well as the most simple of the vegetable, *e. g.*; the *conferva*, the *byssus*, &c. are composed of them. In most of the animal fluids also, as the blood, chyle, saliva, pancreatic fluid, the milk, the spermatic fluid, and the fat, globules have been discovered. They have also been observed in the peculiar juices of vegetables, particularly in those of the lactescent plants. They are found also in the cells of plants, and in the solid tissues of animals, as the cellular, mucous, and serous; in the brain, nerves, muscles, tendons and glands.

These globules, to which there is nothing analogous in minerals, are considered by some physiologists

as the elementary forms of organized bodies, as the ultimate organic molecules, from which, disposed in various modes, the different tissues of animal bodies result. Arranged in lines, they form the fibrous tissues of the nerves, muscles and tendons. Extended in the form of sheets, they compose the various membranes, the serous, synovial, and mucous, and the coats of the vessels. United in masses, they form the solid substance of the glands, as the liver, pancreas, kidneys, salivary glands, &c.

5. The internal structure of organized bodies, presents another very striking characteristic, which distinguishes them from common matter. Mineral substances are formed of homogeneous parts, which are perfectly similar in their physical and chemical properties; while organic bodies consist of various parts, which differ in their forms, properties and functions. A mineral substance may exist either in a solid, liquid, or gaseous form; but it never presents a combination of these forms. It is either wholly solid, wholly liquid, or wholly gaseous. Whereas organic matter always presents a combination of solid and fluid parts. Organized bodies always consist of vascular or porous matter, with fluids contained in its vessels or interstices; and this composition is indispensable to the actions of living matter; for, these result from the mutual influence of the fluids and solids, upon each other. The various parts of which organized bodies consist, perform different functions in the economy of the individual; all of which however concur, each, in a peculiar manner, to the welfare and preservation of the whole. Every organized body is a *system* of organs, and can only exist by the association of these organs; each of these being absolutely essential to the existence of all the others. Whereas mineral bodies present no diversity of structure, and no reciprocal relations of different organs; and the parts, into which they may be divided, can exist separately from their associates, as well as when aggregated together by physical cohesion.

6. These two great classes of bodies, differ also in their chemical composition. A mineral may consist of a single element, or may form a simple body, as diamond, sulphur, &c.; or, it may be composed of a great number of different elements, held together by chemical affinity, or by cohesive attraction. But organized bodies never consist of less than three elements; and animal substances contain at least four, viz. oxygen, carbon, hydrogen, and azote. Carbon may be considered as the characteristic element of one class of organized bodies, viz. vegetables; and azote, of the other, or animal substances.

Further; a mineral has a fixed chemical composition, which undergoes scarcely any change under ordinary circumstances; while organized bodies are subject to incessant changes in their composition, in consequence of certain internal motions, which are continually changing the matter, of which they are formed.

But, another striking peculiarity in the chemistry of organic bodies, is, that they consist of two kinds of elements; one, which may be termed *chemical*, such as exist in mineral bodies, as oxygen, carbon, hydrogen, and azote; and another, which may be called *organic*, because they are the product exclusively of the *organic* or vital forces, and are never found in inorganic matter; such as *albumen*, *gelatine*, *fibrin*, &c. It is owing to the fact, that these last named elements are produced, not by the general powers of matter, but by the peculiar forces of organic life, that it is impossible for us to decompose, and to *reform* organic substances, as we can inorganic. It is only the *general* forces of matter, of which we can avail ourselves in our experiments upon bodies. These will enable us to reduce to their ultimate elements, all kinds of matter, both organic and inorganic. But they will not enable us to recombine these elements in those arrangements, which constitute the organic elements; because this requires the agency of a new species of force, which is wholly out of the sphere of our control. It is not in our

power to create a single particle of vegetable or animal matter; and our analyses of these substances, are in fact nothing else than a more or less complete destruction of their organization.

Another important difference in the chemical composition of organic and inorganic bodies, relates to the mode, in which the elements, which enter into their composition, are combined together. In organic substances, the chemical composition is much more complex than in minerals, and from the same cause, less intimate and fixed. In mineral substances, the combinations are for the most part binary, or their constituent elements are united by *twos*, and their affinities are completely saturated; so that these substances are comparatively fixed in their composition, and have but little tendency to change. However numerous the elements of inorganic substances may be, we always find them forming binary, or, double or triple binary compounds. Water, the earths, the oxyds, and chlorides of metals, the acids, and many other substances, furnish examples of simple binary combinations. The carbonates of lime and of the alkalies, the earthy, alkaline, and metallic salts, glass, &c., are examples of double binary compounds. Solutions of saline substances in water, or the same substances in a state of crystallization containing water, afford examples of triple binary compounds.

It is difficult to form ternary compounds, on account of this strong tendency of the elements of matter, to unite by *twos*. Take water, for example, and we shall find that there are very few simple substances, which it will dissolve. It will not combine with sulphur, carbon, phosphorus, nor with the metals; and, but very sparingly, with the simple gases. But it will readily dissolve all these substances, in some state of combination with other elements. Thus carbonic, sulphuric and phosphoric acids, readily combine with water. Sulphuretted and phosphuretted hydrogen are also absorbed by water, though in very different proportions. The metallic salts, and the alkalies are soluble in water.

If we attempt to form a ternary compound, by uniting a simple body to a substance composed of two elements, the result is, either that no chemical action takes place between them, or, that the simple body exerts so strong an affinity for one of the elements of the compound, as to decompose it. If we add together any number of bodies, having affinities for one another, they never unite into one complex body, but always arrange themselves in binary compounds.

Oxygen, *e. g.*, is one of the elements of organic matter; but it never exists in it in sufficient proportion to saturate the combustible elements, carbon and hydrogen, with which it forms ternary compounds. Hence all organic matter is combustible. It burns when ignited in contact with the air, and then absorbs all the oxygen necessary to saturate its hydrogen and carbon.* In the ternary and other more complex combinations of organic matter, in which the combining elements are held together by a feeble affinity, there is a constant tendency to separate and assume a binary arrangement, in which the affinities are more energetic, and more perfectly saturated. Thus, the ternary combinations of oxygen, carbon, and hydrogen, are resolved by spontaneous decomposition, into the binary compounds, carbonic acid and water. If azote is one of the combining elements, as is the case with animal substances, it separates from the oxygen and carbon, and unites with the hydrogen, for which it possesses a strong affinity, and forms ammonia, which is one of the characteristic results of animal decomposition.

From this tendency of the elements of animal and vegetable substances, to pass into binary combinations, arises the facility with which they are decomposed. The nice equilibrium, in which their elements are held in these complex combinations, can no longer be maintained, after the vital forces, which formed them, have ceased to act. To adopt a familiar illustration, we may say, that the company breaks up and each indi-

* Tiedemann.

vidual joins the friend, for whom he has the strongest attachment.

Though the composition of organized bodies is much more complex than that of inorganic, yet the number of elements, actually employed in the formation of them, is much less than that of those, which exist in the latter. Vegetable matter is composed principally of three elements, viz. carbon, hydrogen and oxygen; and animal matter of four, containing, in addition to the three former, another element, azote, from which it derives its principal chemical peculiarity. Besides these four, which are the essential elements of organic matter, it contains several others, but in very inconsiderable quantities, making in the whole about nineteen, which is little more than one third of the whole number of elementary substances, which have as yet been discovered by chemical researches.

It appears, then, that the structure of organized bodies presents the following characteristic features, viz. that they possess a determinate form and volume; are composed of particles of matter of a spherical shape; and possess a peculiar chemical composition, consisting, in almost all cases, of *three* or *four* ultimate elements, which are always the same, viz. oxygen, hydrogen, carbon and azote; that these are combined together into ternary, or quaternary compounds, not by the operation of chemical forces alone, but by these, modified by a new species of force, the organic, or vital powers; and they are formed into certain organic elements, which the common powers of matter are wholly unable to form, and which, on the contrary, they are constantly endeavoring to subvert; that organic bodies consist of solid and fluid parts; that the solid parts are not compact and homogeneous, but possess a fibrous and vascular, or areolar structure, in which the fluid parts are contained; and, lastly, that an organized body consists of an assemblage of organs, differing in their form, size, structure, and actions, but all mutually dependent on one another, and

conspiring to produce the same result, the preservation and welfare of the individual.

7. The general properties, by which organized bodies are distinguished from inorganic matter, are next to be considered. It has already been observed, that organized substances are not immediately subjected to the laws of chemical affinity, but that they are endued with a new species of force, by which these laws are modified, and which may be termed organic power. In consequence of this peculiar property, organic substances react against the physical and chemical influences of the external world, in a peculiar mode, the intimate nature of which we are unable to discover, while its results are evident and extremely curious. There is a perpetual conflict between organic and chemical power. The physical and chemical forces of nature unite in their endeavors, to reduce under the general laws of matter these isolated masses, which have been wrested from them by a foreign power, which has superseded their own authority, and which is extending its conquests in every part of their empire. In this struggle, the general powers of matter are, in every instance, sooner or later invariably successful. These forces are inherent in every form of matter, unwearied in their exercise, indestructible and inexhaustible; while the organic forces, are by their own nature limited in duration, exist only in connexion with particular forms of matter, isolated from the general mass, and maintained in a forced state of composition by the energy of these very powers, in opposition to the general laws of matter.

But, if organic power is, in every instance, sooner or later overcome and destroyed by the general powers of matter, it is constantly starting up and renewing the conflict elsewhere, and is successful for a time, though, in the end, always overcome by the steady opposition of these powers. So long as an organized body is animated with organic power, so long it resists the chemical influences, to which it is exposed. Even when its organic power is weakened by disease

or natural decay, the chemical affinities of its elements are restrained within very narrow limits; and it is only on the invasion, or near approach, of death in particular parts, or in the whole system, that the chemical forces begin to be developed, in the phenomena of incipient vegetable, or animal decomposition.

This power of reacting against, and neutralizing the mechanical and chemical forces of matter, is exemplified in the faculty, possessed by animal bodies, of preserving a certain regular and invariable temperature, amid very great changes of temperature of the medium, in which they live; in the power of elaborating out of a vast variety of heterogeneous substances, viz. the different kinds of matter used as food, the same homogeneous products, viz. the chyle and blood; and in the power of moulding out of this fluid a great variety of curious tissues and organs, differing in their mechanical structure, in their composition and properties, and all compounded in opposition to the general laws of matter.

All organized beings, both vegetable and animal, are endued with the property of being affected by various external agents, of showing themselves sensible to the impressions which they thus receive, and of being excited by these to certain actions, which inorganic substances never exert. The phenomena of nutrition and growth, under the influence of external agents, imply the aptitude of being affected by the impressions, received from them. Animals of all classes are excitable, their nutrition, and consequently the preservation of their lives, being effected under the influence of external agents, and their voluntary motions being frequently excited by various impressions from without. The egg and the seed are capable of entering upon a series of internal movements and developments, under the influence of warmth, moisture, and atmospheric air.

This property of being determined to certain movements or manifestations of force, under the influence of certain exciting causes or impressions from with-

out, is supposed, by some physiologists, not to be limited to matter already organized and endued with vitality, but to be inherent in organic matter, which is still amorphous and devoid of life. This opinion is founded on what is called spontaneous generation, a process in which certain organic substances, as albumen, fibrin, gelatin, starch, gluten, gum, &c. spontaneously assume, under the influence of certain external circumstances, some of the lowest forms of animal and vegetable life.

9. Another distinctive property of organized bodies is, that their growth and increase proceed from within, while inorganic matter increases by external accretion. The surface, to which the new particles of matter are applied, is *internal* in organic, but *external* in inorganic matter. Organized bodies grow by a series of internal developments; inorganic increase by the addition of matter, applied externally to them. With the nutrition of organized bodies, which is accomplished by the continual intussusception of new matter, is connected an antagonist process of organic decomposition, in which the worn out elements are removed, and discharged; so that a perpetual round of composition and decomposition is going on in all organized bodies.

10. Further; organized substances possess the power of producing beings similar to themselves, or, the faculty of generation. This is a remarkable and exclusive prerogative of organized bodies, unless we admit, with some physiologists, that matter in certain forms and under particular circumstances, has the property organizing itself into some of the lower forms of animal or vegetable life.

11. Organized bodies possess the power of being affected with, and of recovering from disease.

12. Organized substances have a determinate duration or period, beyond which it is impossible to prolong their existence. This period varies for each species of organized being, animal, as well as vegetable. Some insects live but a day, some plants but

a year; while the life of man sometimes reaches to a century, and that of some trees to the term of many hundred, and even, it is supposed, several thousand years. The destruction of organized beings is termed death, to which, there is nothing analogous in the world of inorganic matter; and it is distinguished by two remarkable circumstances, viz. the abolition of the vital forces, or that internal energy, which maintained the organic structure; and the destruction of the body itself by a separation of its elements, effected by the exertion of their chemical affinites, which had been previously controlled and neutralized, as it were, by the vital powers.

CHAPTER III.

Relation of Organized Bodies to Heat, Light, and Electricity.

The relations of organized beings to the imponderable elements, Heat, Light, and Electricity, are of a peculiar kind, and worthy of particular notice.

All organized bodies have, to a certain extent, the power of regulating their own temperature; many of them possess the faculty of exhibiting electrical phenomena of a peculiar kind; and some of them the power of developing light, or of becoming luminous. All these powers are connected with the presence of life, in organized beings. They cease with the extinction of the living principle, with the exception that organic matter, in certain stages, or under certain circumstances of decomposition, is phosphorescent, or becomes luminous in the dark.

Caloric.—Living, or organized matter, possesses the power, to a certain extent, of regulating its own temperature. Living bodies develop heat from the inte-

rior towards the exterior by their own peculiar powers, instead of receiving it from surrounding objects. They do not *receive*, but *produce* it; and they are capable of resisting, to a certain extent, the tendency of calcric to an equilibrium. A part of a living animal, exposed to a considerable degree of cold, instead of having its own temperature reduced, like an inorganic substance, frequently becomes warmer than before; the defect of *physical* heat being compensated by an excess of *organic*. It has been conjectured, that as these two kinds of heat are derived from such different sources, are connected with such different forms of matter and are subject to such dissimilar laws, there may be some essential difference in their nature and properties.

Organized beings differ much in their power of producing heat. As this faculty is connected with the living powers, and the exercise of it is one of the modes of their manifestations, it may be stated generally that those, which are the highest in the scale of development, possess it in the greatest degree. Thus, plants have a lower temperature than animals; and the invertebrated animals a lower temperature than those, which possess a bony skeleton; of the vertebrated animals, also, those which are lowest in the zoological scale, viz. fishes and reptiles, have an inferior temperature to that of birds and the *mammalia*. There are exceptions, however, to this general principle. Birds have a higher temperature than the mammiferous quadrupeds, though they stand lower in the scale of organization. Some of the mammalia, also, have a higher temperature than man. Many insects have a much higher temperature, than would correspond with their position in the zoological scale. Those exceptions, as we shall see hereafter, admit of an explanation, on other principles; particularly that the degree of organic heat in animals, depends on the degree of development of the respiratory organs,—those animals, whose respiratory system is most complicated and perfect, possessing the greatest degree of animal heat. This principle,

however, requires some qualifications. Animal heat is greatest, not absolutely in those animals, in which the organs of respiration alone are highly developed, but in those which, besides, possess a highly developed nervous system, as in the case with birds, when compared with insects.

The human race, and the mammalia, however do not possess so high a temperature as birds, though they have much more highly developed nervous systems; from which it is inferred, that animal heat as far as it is connected with the nervous system, does not depend upon the degree of development of this, absolutely, but only so far as this system is appropriated to the organic or nutritive functions, and its activity is not absorbed in those higher functions of the nervous system, in which the mammiferous quadrupeds, and in a much higher degree, man, surpass the feathered tribe.*

Organized bodies, also, have the power of resisting the heating influence of very high temperature, or of maintaining their own at nearly the same standard under the two opposite circumstances of a higher and a lower temperature of the surrounding medium. When exposed to a degree of heat, superior to the standard of their own temperature, the development of organic heat from within is immediately checked and the excess of caloric applied to the surface, excites the exhaling vessels of the skin to a copious secretion of perspirable fluid, which absorbs the excess of caloric, and flies off with it in the state of vapor. The development of organic heat is checked, under these circumstances, because an excess of external temperature depresses and weakens those functions, by the activity of which caloric is generated in the system. Thus, the nervous power is debilitated by extreme heat; respiration becomes slower and less perfect; digestion, nutrition, secretion, and, in short, all the processes connected with the nutrition of the

* Berthold.

system and carried on in the capillary vessels, where the evolution of animal heat takes place, are more or less enfeebled. Under opposite circumstances, that is, when the surrounding temperature is not sufficiently high, a more active development of caloric takes place from within. All the operations of life are performed with increased energy, as respiration, the action of the nervous system, digestion, assimilation, and the secretion; and with these, calorification.

Plants possess the power of regulating their own temperature in a far less degree than animals. Indeed, some naturalists do not admit that they possess such a power at all. Certain plants, however, especially several species of the *arum*, as the *arum italicum*, the *arum cordifolium*, and *arum esculentum*, develope a high degree of temperature at the period of inflorescence. Hubert found that the heat of the flowers of the *arum cordifolium* rose to 45° Reaumer, when the temperature of the air was only 21° R. The germination of seeds, also, is accompanied with an evolution of heat, a fact, which is exemplified in the process of malting.

Electricity.—There is also an organic electricity, as there is an organic heat. Living beings are idioelectric, i. e., capable of developing electricity, and of exhibiting electrical phenomena by the exertion of their vital powers. Many facts have been observed, by different physiologists, tending to establish the existence of a vital fluid, bearing a very close analogy to physical electricity and galvanism. Beclard observed that needles, plunged into the middle of a nerve, acquired magnetic properties. Beraudi pricked the crural nerve of a rabbit with two steel needles, isolated at their free extremities by a plate of *lac*, and found, at the expiration of fifteen minutes, that the needles had acquired the power of strongly attracting light substances, such as little fragments of paper; from which he inferred, that electricity is developed in the nervous system under the influence of vitality. Another physiologist, Weinhold, asserts that a spark may be

obtained by approximating the two ends of a divided nerve towards each other.*

But the most remarkable examples of electrical phenomena, developed under the influence of vitality, are furnished by certain fishes, which are provided with particular organs for that purpose. Of these fishes there are several kinds, as the *torpedo*, of which there are two species, the *torpedo marmorata*, and the *torpedo ocellata*; the *rhinobatus electricus*, the *tetrodon electricus*, the *gymnotus electricus*, the *trichurus electricus*, and the *silurus electricus*.

The electrical organs of the *torpedo* consist of an apparatus, which may be compared to a battery of several hundred voltaic piles. This apparatus is formed of a great number of prisms, of, from three to six sides, standing very close together, near the head and gills of the fish, and in a direction perpendicular to the surface. These prisms consist of membranous tubes, the sides of which are abundantly supplied with blood-vessels and nerves, and which are divided into cells by transverse membranous partitions. The cells are filled with an albuminous fluid. These organs receive three large nerves on each side, one derived from the fifth pair of cerebral nerves; the two others from the eighth, or the *par vagum*.

As the electrical apparatus of the *torpedo* resembles a battery of voltaic piles, that of the *gymnotus* may be compared to a battery of galvanic troughs. Two of these, a larger and a smaller, are found on each side of the spine, separated from each other by a long ligament, and by the superior muscles of the vertebral column. The larger is found immediately under the skin, along the muscles of the back, and extends to the extremity of the long tail of the fish, where it terminates at a point. A smaller organ is found beneath the former, separated from it by a thick tendinous membrane, a layer of fat, and muscles. The structure of both is similar. They are composed of horizontal membranous plates, separated by an inter-

* Lepelletier.

val of about one third of a line from one another, and crossed in a perpendicular direction by membranous partitions, in such a manner as to form a great number of cells, which are filled with a gelatinous fluid. These organs receive numerous branches of nerves from the spinal marrow, which ramify minutely on the walls of the cells.

The electrical apparatus of the *silurus electricus*, also, resembles a galvanic trough. It is composed of a membrane, situated immediately under the integuments on each side of the fish, arranged in the form of numerous rhomboidal cells, which extend from the head to the ventral fins. These small cells are filled with an albuminous fluid. The organ receives an abundance of nerves from a large branch of the *par vagum*.

The structure of these electrical organs, as well as the phenomena, which they produce, point out a striking analogy between them and the voltaic battery. These organs exhibit, in their structure, a great resemblance to voltaic piles of the second class, inasmuch as they are composed of alternate strata of moist conductors of different kinds, i. e. membranous partitions, and a gelatinous or albuminous fluid. The electrical phenomena produced by them, however, are by no means to be accounted for by their structure alone, or the mechanical arrangement of the parts, which form them, giving rise to electrical excitement merely by contact. For it is found, that the division of the nervous trunks which supply them, immediately destroys their power of giving electrical shocks, although their mechanical structure remains unaffected. From this we must infer, that the electrical discharge of the organs of these fishes is a vital act, which depends immediately on the influence of the nerves upon them; while the electrical organs themselves can only be considered, as a necessary physical condition, or, as contributing, in a secondary manner, to the excitement and discharge, by contact. The discharges seem to be under the control of the animal's will.

The phenomena of these discharges point out a striking analogy between them and the effects of physical electricity. The sensation, produced by the shock, is very similar to that of an electric discharge. The shocks may also be communicated, not only by contact, but by the intervention of substances, which are conductors of electricity. Moistened thread, or cloth, conducts the shock; but if dry, the same substances are non-conductors. According to Humboldt and Gay Lussac, however, metallic substances will not convey the shock of the *torpedo*. The same is true of water, according to the same philosophers; for they experienced no shock on immersing their hands in the water near the fish. The effect was produced only on actual contact. In the *gymnotus electricus*, however, the propagation of electricity by intermediate substances, is much more evident. It sends its shock through the water to the hand placed near it, and small fishes, which are swimming by, are sometimes killed by its discharges, at a considerable distance. Metallic substances, and even wood, placed in contact with the fish, will conduct the discharge; but sealing-wax and bees-wax are non-conductors. Several persons, forming a connected chain, may receive a shock, as from a common electrical machine, if the person, who forms one extremity of the chain, is in immediate contact with the electrical organs of the fish, or is connected with them by means of a conductor of electricity. If the chain is broken by a non-conductor, the effect does not take place. In some experiments, sparks have been observed to accompany the discharges.

Notwithstanding these and other facts, evidently of an electrical nature, there are others, which point out a difference between physical electricity, and that produced by the electrical organs of these animals. Many of the most common effects of electricity, it has been found impossible to produce by means of these organs. Thus, they do not influence, in the slightest degree, the most sensible electrometer. No attraction nor repulsion of light bodies is produced by them. It is impossible to charge a Leyden jar by means of

them; and Davy was unable to effect the slightest decomposition of water, by repeated discharges of a *torpedo*.

The discharge of the electrical organs of these fishes is an act of the will. Unless the animal exerts a voluntary act, no discharge takes place. A strong and vigorous fish has sometimes been seized with both hands, without giving a shock; while, at other times, the slightest contact has been sufficient to excite one. Humboldt is of opinion, that the *torpedo* has the power of sending his shock in whatever direction he pleases. My friend, Dr. Francis W. Cragin, of Surinam, informs me, that the discharge of the *gymnotus electricus* is propagated in every direction, in the water. If the hand be plunged into any part of the tub, in which one of these eels is contained, it will receive a shock, whenever the animal is irritated to make a discharge.

After giving a shock, electrical fishes have the power of speedily charging their battery again. But the fre uent repetition of the discharges exhausts them, and their shocks become weaker, unless they have a period of repose, to recruit their vigor.

The division, or tying of the nerves, which supply the electrical organs, destroys their power of giving shocks. The destruction of the brain of the animal produces the same effect; but the power of giving shocks survives, for some time, the excision of the heart.

There are, however, two electrical phenomena exhibited by animals, which are not of a vital character. One is the production of sparks by the friction of the fur of certain animals, particularly the cat, the rabbit, the dog, the horse, &c. Of the same nature are the sparks, which are frequently observed on pulling off the stockings in cold dry weather, and on combing the hair. In these cases, electricity is excited merely by friction. The galvanic phenomena exhibited by living animal organs, under certain circumstances, are examples of the other. Electricity excited in these cases is not of a vital character, but is produced by the mutual contact of

heterogeneous animal substances, as muscles and nerves, disposed in such a manner as to form a chain; precisely as it is by the contact of different metals with each other, or with moistened substances arranged in the same manner. The effects are still more striking, if the muscles and nerves, which form the animal chain, are armed with metallic coatings, which are made to communicate by means of a metallic wire. In these cases, electricity is excited by the contact of heterogeneous substances.

That electricity should be excited in living bodies, is what we should naturally expect from the fact, that most of the conditions, which are necessary to the excitement of it in inorganic matter, exist in living substances; as, for example, the changes of form and composition, which are constantly taking place in the vital processes of digestion, nutrition, respiration, secretion, the evaporation of liquids, &c. The living body is a laboratory, in which matter is undergoing incessant changes of form and aggregation; fluids are passing into solids, and solids into fluids, and fluids into gases or vapors; and in all these processes, heterogeneous substances, as fluids and solids, are brought into contact, and mutually act upon each other. These circumstances are precisely those, which, in inorganic matter, give rise to electrical manifestations. Most of the operations in nature, in which two heterogeneous substances enter into mutual action, occasion a disturbance of the electrical equilibrium, and the production of electrical phenomena. These considerations, however, will not explain the electricity sometimes developed in the nervous system, under the influence of vitality; particularly the electrical phenomena exhibited by the *gymnotus*, *torpedo*, and other electrical fishes.

Phosphorescence.—Another example of the development of the imponderable elements by organized matter, is furnished by the phosphorescence of many animals and plants. Inorganic substances exhibit this phenomenon under the following circumstances, viz.*

* Tiedemann.

1. Some have the property of shining in the dark, after having been exposed to solar or other light for a certain time. This is the case with the diamond, calcareous spar, marble, strontian, and some other bodies; and in a less degree, with alabaster, salt-petre, muriate of ammonia, galena, &c. The phosphorescence takes place in all transparent media, and even in a vacuum, with a sensible evolution of heat.

2. Many substances shine in the dark, after having been exposed to a certain heat, as chalk, barytes, strontian, magnesia, rock crystal, quartz, topaz; the filings of many metals, as zinc, antimony, iron, silver, and gold. In these cases heat appears to act by overcoming the affinity of these bodies for light, and setting this element free.

3. Friction, percussion and compression, are accompanied with a disengagement of light in many substances, particularly in those, which are rendered phosphorescent by insolation or exposure to heat. Certain fluids, as water and air, give out light, when suddenly compressed.

4. The crystallization of salts, in the water in which they were dissolved, is sometimes accompanied with a disengagement of light. This has been particularly observed in the *sulphate of potash*, and the *fluate of soda*.

5. Intense chemical action is generally accompanied with an evolution of light.

6. Electrical phenomena frequently give rise to a disengagement of light. Some bodies are rendered luminous by the transmission of an electric shock through them; and the fluid itself frequently becomes visible, under the form of a vivid spark.

Many organic substances destitute of life, give out light under circumstances exactly similar; 1. some, after exposure to solar light, as flour, starch, gum arabic, feathers, horn, coral, snail shells, teeth, pearls, bones, &c.; 2. some after exposure to heat, as volatile and fixed oils, sugar, wood, &c.; 3. some, by friction, as sugar, manna, resins, &c.: olive and essential oils, when shaken in a vacuum; 4. all organic bodies

during their combustion; 5. resinous substances, when electrically excited by friction.

Many organic substances, also, are phosphorescent during the process of decomposition. Dead vegetable matter, particularly the wood of trees, and especially that of the roots, when decomposing under the influence of a moderate heat, and of moisture, and without being fully exposed to the atmosphere, is frequently phosphorescent. It is remarkable, that great heat and a freezing temperature, are both destructive of the phosphorescence. The light becomes stronger, but continues a shorter time, in condensed air. In oxygen gas, the phosphorescence is not increased in intensity, but continues a longer time. It ceases in a few hours in azote, hydrogen gas, and the phosphuretted hydrogen, but reappears on the admission of atmospheric air. It disappears in a few minutes in carbonic acid, sulphuretted hydrogen, chlorine, ammonia, and muriatic acid gas. It is speedily extinguished in fixed oils and alcohol, ether, lime water, and diluted acids. It disappears instantly in sulphuric acid. In oxygen, it occasions a loss of the gas, and a production of carbonic acid. From these facts, Gmelin inferred, that during the decomposition of wood, there is, sometimes, formed an organic and very inflammable compound of carbon, hydrogen and oxygen, which, like phosphorus, burns with an evolution of light at the ordinary temperature of the air. It is not improbable, that phosphorus itself may be one of the ingredients of this compound, and contribute greatly to the effect.*

Dead *animal* matter, however, much more frequently exhibits the phenomena of phosphorescence than vegetable. Dead fish, particularly the marine molluscous fish, in the incipient stage of putrefaction, often exhibits it in a high degree. It usually begins a day or two after death, when the animal is exposed to the atmosphere or to oxygen gas, moisture and a moderate temperature. A freezing temperature, and the

* Tiedemann.

heat of boiling water, equally suspend it. The phosphorescence does not appear in a vacuum, in carbonic acid, hydrogen, or sulphuretted hydrogen gas. Lime water, alcohol, ether, and strong solutions of alkalies, salts, and acids, destroy it. But it appears again, when these solutions are diluted with a large quantity of water. On the surface of the fish, during its phosphorescence, a gelatinous fluid matter is observed, which is the source of the luminous appearance. It may be washed off with water, which dissolves it, and becomes luminous itself. The phosphorescence ceases, as soon as the decomposing fish exhales a fetid odor. From these facts it seems probable, that the phosphorescence of dead animal matter is occasioned by its decomposition, followed by the formation of a combustible compound, which probably contains phosphorus, and which burns slowly with the evolution of light, in atmospheric air, or oxygen gas at, a moderate temperature.*

But light is frequently given out by organized bodies, under the influence of vitality. It is asserted by some philosophers, that the flowers of several plants emit luminous sparks after sun-set, in clear warm summer evenings. Several of the cryptogamous plants are said to be phosphorescent. The appearance has been most frequently observed in those, which grow in warm and humid situations, as in mines; particularly in a cryptogamous plant, called the *rhizomorpha*. The phosphorescence of this plant becomes more vivid in a temperature of 40° C. It does not give out light in a vacuum, nor in a gas, which contains no oxygen. It shines brighter in oxygen gas than in atmospheric air, and consumes part of the oxygen, with the production of carbonic acid. The phenomenon ceases with the life of the plant. It seems to depend on the emanation of an inflammable vapor, which undergoes a slow combustion in atmospheric air, and oxygen gas. The *dictamnus albus* is said to diffuse around it, during warm summer evenings, an atmos-

* Tiedemann.

phere, which takes fire on the approach of a lamp, and burns with a brilliant flame.

A great number of animals, also, both aquatic and aërial, exhibit luminous phenomena. Most of the inferior classes of animals, which inhabit the sea, as the *infusoria*, the *medusæ*, the *radiaria*, the *annelides*, many of the *crustacea*, the *mollusca*, and even some of the fishes, are phosphorescent. The luminous appearance of the ocean, which is frequently observed, particularly in the tropical climates, is derived from this source.

The marine animalcula, contained in a vessel filled with sea water, have been observed to be phosphorescent, whenever the water is agitated by shaking the vessel. Diluted sulphuric acid, poured into a vessel containing luminous animalcula, has been found to occasion a sudden brilliant light, which immediately afterwards disappeared. The phosphorescence of the medusæ has been observed to increase, whenever the water containing them was warmed. In alcohol, also, their light became more vivid; but this fluid soon killed them, and their phosphorescence disappeared. The phosphorescence takes place during the motions of the animal, and is more vivid, in proportion to their vivacity and energy.

The light, emitted by some of the phosphorescent marine animals, is most vivid at the time of propagation; and it is asserted by some observers, that even earth-worms are phosphorescent at the period of their amours. A viscid matter exudes from some of the phosphorescent marine insects, which is also luminous, and which communicates a luminous appearance to the finger, and even to the mouth and saliva of those who eat them. The light disappears in a vacuum, but returns on the re-admission of the air. A moderate heat increases its vividness, but the heat of boiling water, or cold, equally destroys it. The phosphorescence continues some time in oil. A dilute solution of muriate of soda, or of nitrate of potash, or, the spirit of sal ammoniac, increases its brilliancy; while concentrated solutions, vinegar, wine, alcohol, sulphuric acid, and

corrosive sublimate, speedily destroy it. It continues some time after death, but is extinguished at the commencement of putrefaction. Among the animals which live in the air, the tribe of insects furnishes the greatest number of phosphorescent animals. The source of the light in insects, has its principal seat in the posterior rings of the abdomen. It seems to reside in a peculiar albuminous matter, secreted by the animal, which is phosphorescent when exposed to a moderate heat, and to atmospheric air; but ceases to emit light when coagulated by alcohol, ether, corrosive sublimate, or concentrated mineral and vegetable acids, &c. The phosphorescence also disappears in the non-respirable gases, and in a vacuum, but returns on exposure to atmospheric air, or oxygen gas.

The phosphorescence usually commences at dusk, and at an earlier period, if the insects be put in a dark place. It seems to be under the control of the animal's will; for, a sudden noise will sometimes instantly cause it to cease. Some naturalists attribute the phenomenon to the action of the nerves; others, to the faculty possessed by insects, of accelerating or retarding their respiration, with which they suppose the emission of light to be connected. It seems to be certain, that the motions of the insect increase the phosphorescence.

The phenomena of phosphorescence require a certain temperature of the air. At a certain degree of cold, the emission of light ceases, and, on the contrary, its vividness increases, if the temperature of the air be elevated within certain limits. If one of these insects, when not emitting light, be plunged into warm water, the phosphorescence commences; and, if the temperature of the water be raised, it increases until the heat reaches a certain point, at which the emission of light ceases. If living insects be plunged into water heated to a degree sufficient to kill them, they emit a very vivid light at the moment they perish.

The phosphorescence requires the presence either of atmospheric air, or oxygen gas. If luminous insects be placed in the receiver of an air-pump, the light which they emit, gradually becomes fainter, in proportion

as the air is exhausted. In oxygen gas, their light becomes very brilliant, and still more so, if the gas be heated. The protoxide of azote produces a similar effect. Chlorine gas destroys them instantly. In hydrogen gas, carbonic acid, sulphuretted and carburetted hydrogen, and azote, which soon kill the insects, the phosphorescence speedily ceases. The emission of light continues some time in warm water, but soon ceases, in alcohol; and is instantly annihilated by the concentrated mineral acids.

An electric or galvanic current, in some instances, has been found to excite a brilliant phosphorescence in the insects exposed to it. Mechanical and chemical irritations, productive of pain to the insect, have also been found to produce the same effect.

Tiedemann supposes, that the phosphorescence of insects depends on a peculiar animal matter, secreted by certain organs. This matter probably contains phosphorus, or some other combustible substance, which combines with the oxygen of the air, or with that contained in the water, at a medium temperature, and thus gives rise to the disengagement of light. The secretion of this substance is an operation of life, and is influenced by various external agents, which exert an influence upon the vital actions of these insects. But the phosphorescence itself is not of a vital character; it depends entirely on the composition and qualities of the luminous matter, and sometimes continues for several days after the death of the animals.*

* Tiedemann.

CHAPTER IV.

Comparison of Animals and Vegetables.

Organized beings are divided into two great classes, viz: animals and vegetables, distinguished from each other by certain characteristic features.

Vegetables are organized living bodies, destitute of feeling and consciousness, and of the power of locomotion. They draw their nourishment from without by absorption at their surface, or by means of roots. They are composed of a homogeneous substance, forming roundish oblong cells, in which the solid or fluid matter of the plant is contained, without presenting any other kind of tissue. They reproduce themselves by temporary organs, which always die before the plants themselves.

Animals are organized beings, endued with consciousness and feeling, and the power of locomotion. All animals, from the zoöphyte to man, are provided with an internal cavity for the reception and elaboration of the food. They are also much more complex in their organization, presenting a great variety of tissues and organs. They contain a much larger proportion of fluid, and a much smaller proportion of solid parts, than vegetables. They are composed of a greater number of chemical elements, and always contain azote in addition to the principles, which exist in vegetable bodies.

CHAPTER V.

Division of the Animal Kingdom.

The animal kingdom presents an immense variety of species, which are arranged in various classes, and subordinate divisions. One of the most general divisions of the animal world, is into *vertebrated* and *invertebrated;* the former, embracing those animals which are provided with an interior bony frame or skeleton; the latter, comprehending all such as are destitute of it.

Again: the vertebrated animals are divided into two great sub-classes, the *warm* and the *cold-blooded* animals; the former, including those which possess a temperature considerably higher than the medium in which they live; the latter, those whose temperature exceeds but little that of the surrounding element. Further; the warm-blooded animals either produce living young which they suckle, or, hatch their young from eggs. The former, or viviparous warm-blooded animals, constitute a great and important division of the animal kingdom, under the name of the *mammalia*; the latter, or the oviparous warm-blooded animals, form the immense family of *birds.*

The cold-blooded vertebrated animals are also divided into two great sub-classes; one includes those which breathe by means of lungs, and comprehends the *reptiles*, forming the four orders, serpents, tortoises, frogs, and lizards; the second embraces the cold-blooded animals, which breathe, not by lungs, but by a different set of organs, called gills; these are the *fishes.*

The *invertebrated* animals constitute the inferior division of the animal kingdom, embracing insects,

worms, the molluscous animals, zoöphytes, and the infusory animalcula.

TABLE OF A CLASSIFICATION OF ANIMALS.

ANIMALS.	VERTEBRATED.	Warm-blooded.	Viviparous, and having breasts. — 1. MAMMALIA.
			Oviparous. — 2. BIRDS.
		Cold-blooded.	Breathing with lungs. — 3. REPTILES.
			Do. with gills. — 4. FISHES.
	INVERTEBRATED.	With articulated bodies.	Articulations, both of the extremities, and of the body; but chiefly of the former. — 5. INSECTS, CRUSTACEA, ARACHNIDÆ.
			Numerous annular articulations of the body. — 6. ANNULATA.
		Unarticulated bodies.	Body naked, covered with a slimy membrane, or inclosed in a calcareous shell. Breathing by gills or lungs, with sexes separate, or hermaphrodite. Blood, white. Head, not distinct from the body. — 7. MOLLUSCA.
			Having a stellated or radiated disposition of the parts, both external and internal, and provided with organs of respiration. — 8. RADIATED ANIMALS. *Sea-nettle, Star-fish, Medusa, Holothuria, &c.*
			Without organs of respiration. — 9. ZOOPHYTES. *Polypus, Coral, Infusory Animalcula.*

The human race belongs to the great class of the *mammalia*, i. e. of warm-blooded, viviparous animals. Some animals of this class approach so near to man in organization, and external shape, that they have received the name of anthropomorphous animals. This is the case with the *simiæ*, or ape tribe. The points of difference, however, are so numerous, as to have led many naturalists to form the human species

into a distinct, and separate class. Some of these distinguishing marks are the following, viz.

1. *The upright position.* That this is natural to man, is evident from the structure of his body, particularly the great size of his head, and the absence of the strong ligament of the neck, with which quadrupeds are provided for the support of their heads; the great comparative size of the lumbar region, the breadth of the pelvis, and of the os sacrum, evidently designed to support a great superincumbent weight; the bulk of the *glutæi* muscles, whose power is exerted in extending the pelvis on the thighs, and maintaining it in that state, in the erect position of the trunk. In the mammalia, even in the *simiæ*, the *glutæus maximus*, which in man is the largest muscle in the body, is very small and inconsiderable. The extensors of the knee joint, also, are much stronger in man than in the *mammalia*. The effect of the action of these muscles, is to preserve an extended state of the limbs, which is essential to the upright position. The *gastrocnemii* muscles, are also much more highly developed in man. We find, accordingly, that no other animal has calves equal to those of man. These muscles are necessary to progression; for, by raising the heel, they elevate the whole body in the act of walking. The concave form of the sole of the foot, and the greater prominence of the heel, designed to give attachments to the strong muscles of the calf, and to support the back of the foot, are further proofs, that the perpendicular position is natural to man. In other mammiferous animals, the *os calcis* does not touch the ground. Many animals, as the dog and cat, do not even rest on the tarsus, but merely on their toes. But, in man, the whole surface of the tarsus, metatarsus, and toes, rests on the ground.

2. *The free use of both hands.* This prerogative of man is evidently connected with the upright position. If two limbs are sufficient for the support and progression of an animal, the two others are left free for other uses. Man is the only *two*-handed animal. The *simiæ*, which approach the nearest to man, are strictly

four-handed, or *quadrumanous* animals, and of course are neither bipeds, nor quadrupeds. They have thumbs on their lower, as well as on their upper extremities; and their feet are instruments of prehension, as well as their hands. In man, the difference in structure between the hands and feet, evidently proves, that they were not intended to perform the same functions. One is organized for support; the other for prehension.

3. *The prominence of the chin*, and the perpendicular direction of the inferior incisor teeth, are also characteristic marks of man, and are found in no other animal. Another circumstance is, that in man the teeth are of the same length; whereas, in other animals the different kinds of teeth differ in length, and are separated by intervals from one another. In inferior animals, the canine teeth are much longer than their neighbors, and are separated from them by a considerable interval.

4. Man is physically defenceless. He is not provided by nature with weapons either for defence, or offence. He remains in a helpless state after birth, longer than any other animal, and is indebted to his reason alone for his instruments of aggression or self-defence.

5. In man the facial angle is greater than in any other animal. In the best formed human head it amounts to between 80° and 90°. In the ape tribe, the facial angle is vastly inferior to that of the least favorable specimens of the human species. The largeness of this angle in man, depends on the great development of the forehead and anterior part of the brain.

6. Man has the largest brain, in relation to the volume of the nerves. This position is generally true, but there are some exceptions to it.

7. Man is the only animal that sleeps on his back.

8. He is the only animal, which possesses an articulate language, expressive of ideas or mental conceptions.

9. He is the only animal endued with reason, and a moral sense.

10. He can adapt himself to greater varieties of climate, and is more widely diffused over the earth's surface than any other animal.

CHAPTER VI.

Anatomical Analysis, or Structure of the Human Body.

The human system is a very complicated machine. It consists both of solids and fluids, or, of containing and contained parts. The fluids constitute much the larger portion of the whole, bearing to the solids the ratio of about 9 to 1, according to some physiologists; or of only 3 to 1, according to others. The first estimate is probably much the nearest the truth.

The solids are composed of the same chemical principles as the fluids, and are, by analysis, reducible to the same ultimate elements. This follows as a natural consequence from the fact, that the solids are formed out of the fluids, by new combinations of their particles, under the direction of vital or organic affinity. In the formation of the solids, the particles of matter are arranged in various modes. If we may believe some microscopical observers, the ultimate animal solid is a minute sphere or globule of matter of extreme minuteness, not exceeding in diameter the 8000th part of an inch. This is supposed to be the ultimate mechanical element of the animal organization, from which, disposed in various modes, are formed a great variety of animal solids. These may be arranged in the order of their simplicity, into filaments, fibres, tissues, organs, apparatuses, and systems.*

* Library of Useful Knowledge; Article, Physiology.

A *filament* is composed of a series of the primitive molecules, arranged longitudinally, or in a row. Several of these filaments, united together in a bundle, form a *fibre*. In this manner are formed the muscular and nervous fibres. A *tissue* is composed of fibres, disposed collaterally or in planes, so as to form an expansion or membrane; or, intersecting one another at various angles, in such a manner as to form spongy solids with areolæ or interstices, dispersed throughout them. The cellular, serous, and mucous tissues are thus formed. Different tissues, disposed in a certain manner, so as to form a distinct piece of animal mechanism, designed to perform a particular office, constitute an *organ*. Thus a muscle, a nerve, a bone, the stomach, the brain, &c., are organs. Some of the organs are extremely complicated in their structure, as the eye, the ear; the viscera contained in the great cavities, as the lungs, liver, intestines, &c.

Sometimes several organs are associated together for the purpose of accomplishing a common object. Such an assemblage is called an *apparatus*. Thus, the apparatus of digestion consists of the mouth, teeth, œsophagus, stomach, intestines, liver, pancreas, lacteals, &c.; all of which organs concur toward the same object, the assimilation of food.

The term *system* is applied to an assemblage of organs, which possess the same, or a similar structure. Thus, the nervous system consists of a variety of organs, which, however differing in figure, magnitude, and situation, agree together in possessing one common structure. The same is true of the muscular system, that of the bones, ligaments, vessels, &c.

The first step in organizing the animal frame out of the primitive molecule, is the formation of the filament, which may be regarded as the elementary animal solid. The next is the formation of the fibre, by the union of several filaments in a bundle. The fibres may be regarded as elementary, in relation to the tissues, which are all formed out of fibres.

CHAPTER VII.

Fundamental Tissues.

The solid part of the body is formed out of three fundamental tissues, the *cellular*, the *muscular*, and the *nervous*. All the solids of the body, however numerous, and however widely they may differ one from another, as the bones, ligaments, cartilages; the vessels, muscles, nerves, &c. may be analyzed, anatomically, into one or more of these three.

Of these tissues, the most generally diffused, and the simplest in structure, is the *cellular*. This tissue enters into the composition of every organ, and is the basis of the solid structure of the body. It forms, in fact, a kind of frame-work of the body, so that if every other kind of animal matter were removed, the cellular tissue alone would preserve the exact figure, and present a perfect skeleton of the whole, and of every one of its parts. Into the *areolæ*, or interstices of the cellular membrane, all other kinds of animal matter may be considered as infused. Thus, the bones are formed of an earthy salt, the phosphate of lime, infused in cells formed of cellular tissue. The muscles are bundles of fibres, inclosed in a sheath formed of cellular membrane. Every fasciculus of these fibres has a sheath of this tissue; and every individual fibre, which goes to the formation of a muscle, has an envelope of cellular membrane. The same tissue, also, forms sheaths for the nervous cords. These sheaths send fine processes within, which surround the bundles of nervous fibres, and connect them together. The greater part of the ligaments, tendons, and cartilages, are composed of cellular tissue. It even constitutes a very considera-

ble part of the hair and nails. This tissue, also, penetrates into the interior of the solid viscera, as the liver, pancreas, and other glands, and the coats of the hollow organs, as the stomach, intestines, vessels, &c.; where it serves the purpose of connecting and binding together the tissues, of which they are composed.

The cellular tissue, then, it appears, occurs in two forms. In one, it constitutes the basis of all the solids of the body; in the other, it serves as a bond of union, by which the organs are connected together. The first, by some physiologists, is termed the *parenchymatous;* the second, the *atmospheric* cellular tissue. The latter fills up the intervals or spaces between the organs; while the former enters into the texture of the organs themselves, and contains all the other tissues, of which they are composed.

The cellular tissue, however, though entering into the composition of all the organs, which perform every variety of function, yet never loses its own character, which is everywhere the same; nor participates in that of the organ, which it contributes to form. Though present in the nerves, and penetrating into the very recesses of these organs, yet it does not share in the sensibility, which is the peculiar attribute of the nerves; and, though it accompanies every muscle and every muscular fibre, it no where partakes of the irritability, which belongs to these organs. Though it exists in the glands, it has no concern in the secretion of their peculiar products.

The cellular tissue appears to be composed of fibres of extreme delicacy, intersecting one another in every direction, so as to leave between them interstices, or little cells, from which it derives its name. This structure, however, appears only where the tissue is subjected to a slight distention, and it entirely disappears, when the distending cause ceases to act; for the cellular tissue is extremely elastic and contractile, except in plants, in which it forms cells of regular shape, with firm walls. In animals, in the living state, it appears as a soft, loose, elastic, semi-fluid sub-

stance, of a grayish color; sometimes it presents a slimy appearance. It gives passage to some blood-vessels and nerves, which, however, are destined to other parts, and are not spent on the cellular tissue itself. It is abundantly supplied with colorless vessels, and particularly lymphatics, which absorb the aqueous or oily fluid, contained in its cells.

This tissue, as it exists in every part of the body, forms a connected whole, or an immense net-work, every where permeable to air. If air be forced into its cells in any part of the body, with a moderate continued force, it gradually penetrates and pervades the tissue, so that the whole of it becomes inflated. As it exists in the living body, its cells, where it enters into the composition of the organs, are filled with the parenchyma of these, and in other places, either with a watery halitus, or an oily fluid.

The uses of this tissue may be inferred from what has been said. It forms a basis for all the solid organs, and it connects the solid parts of the body together; and, by its softness and elasticity, and the oily fluid with which its cells are filled, it promotes the mobility of the parts on one another. Its fundamental physiological property is *contractility*, or, *animal elasticity*, which it imparts to all the organs it contributes to form; and its chemical characteristic is its being composed chiefly of *gelatin*.

Out of the cellular tissue are formed a great variety of others, which may be regarded as modifications of it. These are *membranes* of all kinds, the sheaths of the muscles and nerves, vessels, and other organs.

The *membranes*, which are formed of the cellular tissue, constitute some of the most important structures of the body. The general covering of the body is formed of membrane. Each individual structure has its membranous covering. All the cavities, in which the principal organs are enclosed, are lined by membrane. The vessels are composed chiefly of membrane. Even the solid organs, as already observed, are formed of a basis of membrane, into the areolæ of which, as a mould, is infused the peculiar animal mat-

ter belonging to them respectively. Now, all these membranes are merely modifications of the cellular tissue.

The principal varieties of membrane, which require to be noticed, are the following, viz. the *serous*, the *mucous*, the *dermoid*, the *fibrous*, the *cartilaginous*, and the *osseous*.

1. *The serous membranes.*—The serous membranes line all the closed cavities, or sacs of the body, and are reflected over the organs, contained in them. Thus, the cavities of the chest, the abdomen, brain, and joints are lined by serous membrane. These membranes separate dissimilar or heterogeneous parts from each other. Wherever a cavity exists in the body, containing parts or organs differing in structure from the walls of the cavity, such cavity, as well as the contained parts, are lined by a serous membrane. Thus, in the cavity of the abdomen, which contains the great organs subservient to digestion; in the cavity of the chest, which contains the lungs; between the lungs themselves, where the heart is situated; in the ventricles of the brain, where the *plexus choroides* is found, we find, severally, a lining of serous membrane, which is reflected from the walls of the cavity, over the organs contained in it. The cavities of the joints belong to the same category, and, accordingly, the synovial membranes, which line them, are classed with the serous membranes. The *bursæ mucosæ* belong to the same structure. The *arachnoides*, which lies between, and separates the *dura mater* and *pia mater* of the brain and spinal marrow, is also regarded as a serous membrane.

The serous membranes, it appears, enclose, chiefly, the organs of automatic or involuntary motion. They envelope the heart, the lungs, and the intestinal canal, and the glandular and other organs connected with it, and some of the organs of reproduction. According to Rudolphi, serous membranes line, not only the closed cavities of the body, but the interior of the vessels also, and the canals, which open outwardly, as the alimentary canal, and

the air passages, forming a cuticle over the mucous membranes which line these passages, analogous to that which covers the external skin.

These membranes are of a shining whitish color, and smooth on their free or inner surface, which is moistened with a watery halitus, from which they derive their name. On their attached, or external surface, they are rough, like condensed cellular membrane, and are connected with the walls of the cavities which they line, by means of cellular tissue. They are extremely elastic and extensible, as appears from the shrinking of serous sacs, after the removal of collections of water, or of any other cause which has distended them. They are said to be destitute of blood-vessels and nerves, and to consist merely of condensed cellular membrane, in which, it is asserted, the microscope cannot detect the least trace of a vessel. The serosity, which exhales from, and moistens them, is merely an exudation from the vessels beneath them, and is probably transmitted by inorganic pores. The intense inflammation sometimes affecting the walls of the cavities which are lined by them, and which is usually referred to the serous membrane, is supposed, by some anatomists, to be seated in the tissues immediately subjacent to them.

The uses of the serous membranes are to separate heterogeneous parts, or organs; and to diminish friction, and facilitate the motion, or gliding of these parts upon one another by means of their moist and polished surfaces.

2. *Mucous membranes.* Another class of membranes, formed out of the cellular tissue, and possessing a higher degree of organization than the serous, are the *mucous membranes*, so called from the viscid fluid, which it is their proper office to secrete. These membranes line all the cavities, which open upon the surface of the body, as the digestive and urinary passages, the nasal cavities, and the air tubes. They enter into the structure of the different organs, which are concerned in the prehension, and assimilation of the aliments, in aërial respiration, and the secretion,

and excretion, of the various fluids. They may be considered as the basis of the glands, into the substance of which they everywhere penetrate; the inner tunic of the excretory ducts, even to their radicles, where they anastomose with the capillary parenchyma of the glands, being always formed of mucous membrane. According to Rudolphi, these membranes have no free surface, but always lie between two others, having on their inner surface a thin serous tissue.

The mucous membranes, with scarcely an exception, form a continuous whole. That, which lines the eyes and eye-lids, is connected by means of the nasal canal, with the membrane, which invests the cavities of the nose. In the throat, the lining membranes of the mouth and nose pass into each other; and they detach a process, which passes through the canal of Eustachius into the cavity of the tympanum. In the fauces, the mucous membrane divides into two great branches, one of which passes through the larynx and trachea, into the lungs, and furnishes a lining to the air tubes in all their branchings; the other follows the route of the pharyx and œsophagus into the stomach and intestines, which it lines throughout their whole extent. In the small intestines, it sends detachments to the liver and pancreas, through the biliary and pancreatic ducts, which penetrate, by the ramifications of these ducts, into the very parenchyma of these glands.

Another branch of the mucous membrane lines the passages of the urinary and sexual organs. In the male it invests the *urethra*, and bladder, and passes thence through the *ureters* into the kidneys; another branch passes into the *vesiculæ seminales*, and thence through the spermatic cord into the *testes*. In the female it lines the vagina and uterus, and passes thence through the fallopian tubes into the ovaries.

The branch of the mucous membrane, which invests the urinary organs, apparently has no connexion with that, which lines the alimentary canal. For, the perineum covered by the common integuments, intervenes

between the outlets of the digestive and urinary passages. In some animals, however, these canals have a common outlet, and consequently the mucous membranes, which line them, are continuous with each other. This is the case with birds. In the mammalia, also, the skin, which covers the perineum, approaches, in its organization to the mucous membrane. The mucous membranes which line the excretory ducts of the breast, and the external ear, are isolated from the rest.

The mucous membranes, as before remarked, are more highly organized than the serous. They are of a loose, spongy texture, and of a reddish color, and are largely supplied with blood-vessels and nerves. They are furnished with numerous small glandular bodies, called mucous glands or follicles. In a healthy state, these membranes are always covered with a slimy substance, which is secreted by them, and from which they derive their name. The uses of these membranes are to sheathe and protect the inner surfaces of the body, as the skin does the outer; and, by means of the mucus secreted by them, to screen these surfaces from the contact of irritating substances, which may either be introduced from without, or generated in the body itself. Like the cellular tissue, the mucous membranes are highly extensible and elastic.

3. The *skin*, or *cutis*, which forms the outer covering of the body, forms another variety of membrane, which is a modification of the cellular tissue, and which bears a close analogy to the mucous membranes. About the orifices of the internal canals, the skin and the mucous membranes pass into each other, as in the lips, nostrils, eyelids, external ear, rectum, &c. Like the mucous membranes, the skin is largely supplied with blood-vessels and nerves, and in many parts with small glandular bodies, called sebaceous glands. On the face, and many other parts, it is thin and delicate; in the palms of the hands, and soles of the feet, and some other places, much thicker. It is covered, externally, by the cuticle, or *epidermis*, an inorganic membrane, destitute of

vessels and nerves, wholly insensible, and easily renewed, if removed or destroyed. The inner surface of the cuticle is lined by a fine tissue, called the *rete mucosum*, by which it is united to the *cutis*, and which, by some, is regarded as a distinct membrane; by others, merely as compacted mucus. It is very soluble; and in the Ethiopian race, in which it is thicker than in the light-colored varieties of the human species, according to Blumenbach it may be completely separated both from the cutis and cuticle, and made to appear as a distinct membrane. It is the seat of color in the human race, the cutis itself being white, and the cuticle, semi-transparent. The sebaceous glands of the cutis secrete a thin oily fluid, which is diffused over the skin, and preserves its suppleness and moisture. The skin is very extensible and contractile.

This membrane is one of the principal organs of relation; by means of which, a communication is established between us and the external world, and by which we obtain a great number of ideas of the qualities of external bodies, as heat, cold, hardness, form, distance, &c. To qualify it for this function, it possesses great sensibility, which it derives from the cerebro-spinal nerves, with which it is plentifully supplied. It, also, gives passage to fluids from the system under the form of insensible perspiration, or sweat, and is an absorbing, as well as an exhaling organ. It seems, also, to protect the system against the irritating contact of external bodies, and to modify the impressions received from them, so as to disarm them of their hurtful properties.

4. Another class of membranes, formed out of condensed cellular tissue, are the *fibrous*, so called from their texture. To this structure belong the *periosteum*, the *dura-mater*, the *aponeuroses*, the *fasciæ*, the *perichondrium*, the *tunica-albuginea* of the *testes*, and of the *ovaries*, the coverings of the kidneys, and spleen, and the *sclerotica* of the eye. The fibrous structure, also, appears under another form, that of thick bundles of different shapes, as in the ligaments and tendons.

The color of this tissue is generally of a pearly white, with a satin-like or argentine lustre. Its texture is essentially fibrous. The fibres, which compose it, are delicate and intimately connected together, so that it is difficult to separate them. It seems to consist principally of condensed cellular tissue. The fibrous tissue is sparingly supplied with vessels, particularly in adult age; but in the fetal state, and in infancy, its vessels are much more abundant and conspicuous. Certain parts of this tissue, also, are highly vascular, as, for example, the periosteum and dura-mater; while, in certain other parts, it seems to be wholly destitute of vessels. The existence of nerves, in the fibrous tissue, has not been clearly demonstrated.

This tissue possesses but little elasticity, and scarcely any extensibility; but its strength and tenacity are very great. It possesses no irritability, and in a normal state, no perceptible sensibility. Yet the distension, which precedes the rupture of the ligaments, and the wrenching of the same parts, in injuries, are productive of violent pain. In morbid states, the fibrous tissue is sometimes the seat of very acute sensibility.

The functions of this tissue, as it exists in the form of ligaments and tendons, are essentially mechanical. It chiefly serves to form bonds of connection, by which the bones are united together, and the joints strengthened; and firm solid conductors of muscular motion to the bones, which the muscles are designed to move. In the form of membrane, it furnishes strong sheaths or envelopes to many parts, as the *corpora cavernosa*, the eye, the kidneys, spleen, testicles, the tendons, bones, and cartilages.

5. The *cartilaginous tissue* is another modification of the cellular, appearing to consist of condensed cellular membrane and gelatin. Cartilages are firm, smooth, highly elastic substances, of a pearly white color, and which become semi-transparent by drying. With the exception of the bones, they are the hardest parts of the animal frame. They are destitute of red vessels, and neither nerves, nor lymphatics, have been discovered in them. They unite with great difficulty

after wounds. Cartilages are invested with a fibrous membrane, called *perichondrium*. They differ from bones in containing no phosphate of lime, and in the want of cells and cavities for containing marrow.

Cartilages are divided into two kinds, the *permanent* and the *temporary*. The *temporary* are those, which are destined to be converted into bone; for all the bones were originally cartilaginous. The *permanent* are those, which are not destined to future ossification, though they are liable to a morbid process, by which they are converted into bone. Thus, the cartilages of the ribs, those of the larynx and trachea, and even the epiglottis, are sometimes found ossified. Naturalists have, even, observed examples of ossification in the cartilaginous fishes, in which, in the normal state, the skeleton remains cartilaginous during the life of the animal.

The *permanent* cartilages are found in various situations, and perform various offices in the system. In some instances, they constitute the basis of organs; of which we have examples in the cartilage of the ear, that of the nose, and those of the larynx and trachea. Sometimes they exist between bones, which are not susceptible of motion upon each other, as between the bones of the cranium; sometimes, between such as admit of a certain degree of motion upon one another, as the intervertebral cartilages, and those between the bones of the pelvis; they also tip the articular extremities of the long bones which move freely upon each other, in the cavities of the joints. To these may be added the cartilaginous prolongations of the ribs.

6. The *osseous tissue*, which constitutes the bones, is the hardest part of the human body. The basis of it is cellular tissue, which is infiltrated with an earthy salt, the phosphate of lime. If this be removed, the bones appear as cartilages, and, by long maceration, they are at last reduced to cellular tissue. The bones are formed from cartilages, as is evident from the process of ossification, in which the future bone always appears first in the form of cartilage. In the fetal state all the bones are cartilaginous. The structure

of bones belongs to that variety of the cellular tissue which is called fibrous. The fibres follow no regular course, but intersect each other in every direction. The osseous tissue, like the cartilaginous, is said to have no proper nerves; yet Mr. Swan has given us the view of a nervous cord passing directly into a bone. The blood-vessels of this tissue, which, in its early period of development, are numerous, gradually diminish, and with them, its powers of nutrition and reparation. The bones are covered with a fibrous membrane, called the *periosteum*, which may be considered as an expansion of the tendons of the muscles over the bones. The muscles are attached to the bones by means of the periosteum only. Into this membrane pass the nutritive blood-vessels of the bones, some of which branch over the periosteum, and others penetrate into the substance of the bones. In certain places, where no muscles are attached to bones and no periosteum is formed, a distinct membrane is provided to supply its place. This is the case with the inner surface of the cranium, where a strong fibrous membrane supplies the place of an internal periosteum. The inner surface of the hollow bones is lined with a serous membrane, called the *periosteum internum*, or medullary web, which secretes the marrow. This is plentifully supplied with blood-vessels.

The bones may be divided into three kinds, the roundish or spongy bones, as those of the hands and feet, and the vertebræ; the cylindrical or tubular bones, including those of the arms and legs; and the flat bones, as the shoulder-blades and the bones of the cranium.

The bones are of a yellowish white color, and smooth externally; internally they present different kinds of structure. The broad flat bones consist of two tables, between which a cellular structure intervenes. In the cylindrical bones, the middle part is hollow, forming a tube with firm, hard walls, but the two extremities are spongy or cellular. The cells and cavities are filled with an oily substance, called marrow.

The bones form a connected system, which constitutes the basis of the whole frame. They are the hardest part of the body, and serve as the frame-work and support of all the soft parts. They serve as points of attachment to the muscles, or moving powers, and constitute levers of various kinds for the muscles to act upon, in executing the various motions which the body has the power of performing.

Ossification is frequently a morbid process, occurring in a variety of structures, and impeding the functions of the parts. Thus, the coats of the arteries, the valves of the heart, the tendons, and even certain muscular parts, as the substance of the heart, sometimes become bony. The same structures are sometimes converted into cartilage.

II. Another constituent part of the system is the *muscular fibre.* To this appertains another of the elementary properties of life, viz. *irritability,* or the faculty of contracting or shortening itself on the application of certain stimuli. It is as peculiar, also, in its chemical constitution, as it is in its structure and its vital properties, being formed almost wholly of concrete fibrin.

The ultimate muscular filament is extremely minute, not exceeding, according to some physiologists, the fifth part of the diameter of a red globule of blood. The visible fibres, into which the bundles of muscular flesh may be mechanically divided, are cylindrical in their shape, and of a reddish color, which is supposed to be owing to the blood which they contain. The ultimate fibres are united into bundles, called *fasciculi,* or *lacerti;* and these, by their aggregation, form the fleshy masses, which are called muscles. Every fibre and fasciculus is enclosed in a sheath of cellular tissue, and the whole muscle has an envelope of the same; so that the cellular tissue is largely incorporated into the substance of the muscles, to which it imparts its own peculiar property, animal elasticity.

The cellular substance, which thus exists between the fibres and fasciculi of the muscles, becomes thicker and more condensed, and constitutes a larger proportion of the whole mass, while the muscular fibres

diminish, in receding from the middle and approaching the extremities of the muscles, where they terminate in tendons. And it is in this mode, that the tendons are formed out of cellular tissue. For, towards the extremities of the muscles, this tissue becomes more condensed, and forms an increasing proportion of the whole mass of the organ, until the muscular fibres wholly disappear, and the whole cellular tissue belonging to each fibre and fasciculus, prolonged beyond the termination of the muscle, and condensed together, appears in the form of a silvery white cord of a cylindrical or flattened shape, called tendon. The tendons then, it is evident, must be connected with every fibre of the muscles to which they belong. They are destitute of the irritability of the muscles, but are elastic like the cellular tissue, of which they are formed, and they consist principally of gelatin.

The muscles are the instruments by which most of the sensible motions of the system, both voluntary and involuntary, are executed.

III. The third constituent element of the structure of the body, is the *nervous fibre*. This consists essentially of *albumen*, as the muscular fibre consists of *fibrin*, and the cellular tissue of *gelatin;* and it is endued with a distinct physiological property, *sensibility*.

A nerve consists of two elements, viz. a pulpy or medullary matter, i. e. the peculiar matter of the nerve, and a sheath which invests it, formed of cellular tissue. The medullary substance consists of bundles of nervous fibres, each covered with its own sheath of cellular tissue or membrane, and each also being divisible into a finer series, until we arrive at the ultimate nervous filament. This appears to be destitute of a cellular sheath; but the primitive nervous fibre, formed by an aggregate of filaments, is invested with a sheath, and every fasciculus in like manner has its own envelope of cellular tissue; and lastly, the nerve itself, formed by an aggregate of fasciculi, has a common sheath, which is called the *neurileme*. According to Fontana, the ultimate nervous filament is twelve times larger than the primitive muscular.

Of nervous matter is formed the nervous system, consisting of the brain, spinal marrow, the ganglions, and the nerves themselves. Its elementary physiological property, as before remarked, is sensibility, which it communicates to all parts of the system, to which nerves are distributed. The sensibility thus diffused throughout the sytem, has two principal centres or foci, viz. the *brain*, and the *great solar plexus;* and it bestows unity and individuality upon the whole assemblage of organs and functions, of which the living system is composed.

CHAPTER VIII.

The Compound Structures of the System.

Out of the elementary tissues, which have thus been briefly described, viz. the cellular, muscular and nervous, are formed the various organs which compose the system of the animal. The principal of these are the bones, cartilages, ligaments, muscles, nerves, vessels, viscera, and organs of sense.

The two first of these, viz. the bones and cartilages, have already been sufficiently described, under the head of the osseous and cartilaginous tissues. The functions of these, together with those of the ligaments and tendons, are essentially mechanical.

The ligaments constitute a structure, the chief use of which is to connect the bones together into one system; though there are many other structures which resemble the ligaments, which are destined to very different uses; as *e. g.* the *sclerotica* of the eye, the *dura-mater*, the *periosteum*, the *aponeuroses* of the muscles, the *fasciæ*, the white tunic of the testes, and

ovaria, and the proper coat of the kidneys and spleen. These, with the ligaments, constitute collectively, the *fibrous system.* The common character belonging to all these tissues, is a distinctly fibrous structure. In consequence of a deficiency of nerves, they possess scarcely any sensibility, except to mechanical violence of a certain kind, as, e. g. *wrenching;* and, as they contain scarcely any blood-vessels, they are of a white shining color. They are very firm and compact in their texture.

The proper ligaments are of different shapes; some being round, some broad, and others forming sacs, as the capsular ligaments. They serve to connect together the articular ends of the bones in forming the joints.

The ligaments are intimately connected with the periosteum of the bones, as they spring from this membrane and are again inserted into it. In some few examples, however, they are connected, not with the periosteum, but with cartilages.

The capsular ligaments, which enclose the articulations, consist of two coats, of which the outer is fibrous, and the inner, serous. The serous forms a closed sac, and is a secretory membrane, by which is prepared the synovial liquor.

The *muscles* constitute another very important class of organs, consisting of muscular fibres, collected together into bundles by the intervention of cellular membrane, and plentifully supplied with blood-vessels and nerves. They are the organs of motion, and of the voice, and are divided into two classes—first, muscles of voluntary, and secondly, those of involuntary motion; or, as they are sometimes termed, muscles of *animal* and those of *organic* life. Those of the first class constitute the fleshy parts of the body. They lie more exteriorly, or towards the periphery; derive their nerves principally from the spinal marrow; act in the normal state only under the control of the will; are attached by both extremities to bones; and are the organs of the voluntary motions of the body.

The second class, or the muscles of *organic* life, are found in the interior of the body. These receive their nerves principally from the ganglionic system. They are not attached to bones, and are hollow organs, which do not contract under the influence of the will, but in consequence of certain natural stimuli, applied directly to them. The heart, the stomach, intestines, bladder, and, according to some physiologists, the air-tubes of the lungs, belong to this class of muscles. Animal motion, however, is not, in all instances, executed by muscles. The motions of the blood in the capillary vessels and veins, that of the lymph and chyle in the lymphatics, that of the different secreted fluids in the excretory ducts, the contractile motion of the cellular tissue and of several of the membranes formed out of it, as the skin, the serous and mucous tissues, &c. are not executed by a muscular structure.

The *nervous system* constitutes another very important system of organs, consisting of the brain, spinal marrow, ganglions and nerves. Like the muscular system, it is divided into two great sections, one termed the nervous system of *animal*, the other, that of *organic* life. The first consists of the brain and spinal marrow and the nerves proceeding from them; the second, of the system of ganglions and the nerves to which they give rise. The nervous system of animal life, presides over cerebral sensation and voluntary motion. The nerves, belonging to it, are connected by their central extremity with the brain or spinal cord, and, by their peripheral, with the organs of sense, or the muscles of voluntary motion; and they are channels of communication between the centre and the periphery of the nervous system of animal life.

The nervous system of organic life, presides over organic sensibility and involuntary motion. Its nerves are distributed to the hollow viscera of the thorax and abdomen, and to the coats of the blood-vessels, which they accompany to all parts of the body. The functions of the circulation, of nutrition, secretion, exhalation, absorption, &c., are supposed to be under the control of this part of the nervous system.

The *vascular system* constitutes another very essential part of the human body. It embraces various organs, which differ in structure and in functions, but which agree in general in this respect, that they consist of cylindrical canals or tubes with membranous coats, which contain some kind of fluid, and do not open outwardly. By means of this system, certain substances, designed for nourishment or respiration, as aliment and the oxygen of the atmosphere, are introduced into the body, where, after undergoing certain changes, they are made to repair the waste in the organization, occasioned by the operations of life. By the same system, materials unfit for nutrition, whether introduced from without, or developed in the body itself, are conducted to some excretory organ, by which they are afterwards discharged. By the vascular system, the blood, the great excitant of the organs, and the source from which are derived the materials employed in the various processes of life, is distributed to all parts of the body, which are nourished and excited by it.

The vascular system is divided into three great branches, viz. the *arterial*, the *venous*, and the *lymphatic*. The first, or the arterial, carries red blood from the heart to all parts of the body; the second, or venous, brings back purple blood from all parts of the body to the heart again; and the third, the lymphatic, also called the absorbent system, carries white or colorless fluids from the interstices and periphery of the body, and from all the organs, into a large trunk, which opens into the venous system near the heart. The lymphatics, as yet, have been discovered only in the mammalia, birds, reptiles and fishes. They originate from the various membranes, the basis of which is condensed cellular tissue, as the mucous, serous, synovial and dermoid, as well as from the cellular membrane itself, which fills the interstices and forms the basis of the organs. They communicate with the venous system by means of the great lymphatic trunks, and, as some physiologists assert, by direct anastomosis with the veins; so that they are regarded as an appendage of

the venous system. Their function is to absorb the nutritive fluid prepared by digestion in the alimentary canal, as well as other substances, which may come in contact with the external integuments of the body, and the mucous membranes. They, also, re-absorb certain parts of the various secreted fluids, and they are supposed to be the principal agents of the decomposition of the solid tissues and organs; the molecules of which they detach and absorb, convert into a fluid state, and convey into the mass of the venous blood.

The *arteries* are composed of three coats; first, an external, formed of condensed cellular tissue, and possessing considerable strength and elasticity; second, a middle, or the proper coat of the arteries, the real character of which is a subject of some controversy. It is a very firm, thick and elastic tunic, composed of circular fibres, of a yellow color, and possessed of little or no irritability. According to Berzelius, it is wholly destitute of fibrin, in which respect it differs essentially from the muscular tissues. The third, or internal coat, is smooth and polished, and is said to be lubricated with a kind of serous exhalation.

The *veins* in their structure, differ somewhat from the arteries. Like these, they are composed of three coats, an external, middle and inner. The external consists of cellular substance, is dense, and difficult to rupture. The second, or middle, is considered as the proper coat of the veins. It is said to be composed of longitudinal fibres, but, according to Magendie, it contains a multitude of fibres interlacing one another in all directions. Like the middle tunic of the arteries, it is insensible to the galvanic influence, and is not supposed to be muscular. It seems to be doubtful, whether it contains fibrin or not.* The third, or

* The middle coat of the blood-vessels, is regarded, by many anatomists, as a distinct tissue of a fibrous structure and peculiar nature. It is either of a yellowish white, or pale reddish color, and is called the vascular fibre. It contains no fibrin, nor does it respond to many irritations which excite muscular contraction, as galvanism, and mechanical irritation. It appears, however, to possess a peculiar vital contractility, which differs from muscular irritability. In the arteries, this tissue embraces these vessels circularly; in the veins, it is disposed longitudinally. The lymphatics are destitute of it.

interior coat, is extremely thin and smooth, and serves to facilitate the motion of the blood by diminishing its friction. It is susceptible of great distention, without being ruptured. It forms in the cavities of the veins, numerous folds, which perform the function of valves.

The *lacteals* and *lymphatics* are composed of two coats only, viz. an external and an internal; the external, of a firm, fibrous nature; the internal, very thin and delicate. Like the veins, the lymphatics are supplied with numerous valves.

The *visceral system* comprehends the large organs contained in the great cavities of the thorax and abdomen, as the lungs, the stomach, intestines, liver, spleen, pancreas, &c. The heart is excepted, as belonging to the vascular system, and the brain, as being part of the nervous; and hence these two organs are not considered as being strictly *viscera*. The viscera are the most complicated parts of the animal system, with the exception of the organs of sense, which are properly appendages of the nervous system. They are the seats and the instruments of the great functions of *digestion* and *respiration*.

CHAPTER IX.

Fluids of the System.

The fluids constitute much the larger proportion of the whole system. They are of various kinds, and perform very different offices in the animal economy. They may be distributed under three general heads, viz. I. those which serve for the preparation of the blood; II. those which are formed out of the blood; and III. the blood itself.

I. Those which serve for the preparation of the blood, are two, viz. the *chyle* and the *lymph*. The chyle is a thick, cream-like fluid, prepared from the aliment by the powers of digestion, and imbibed from the small intestines by a branch of the absorbent system, viz. the *lacteals*, and carried into the circulation by the thoracic duct. It is destined to repair the losses of the blood, to which fluid it bears a close analogy in its constitution and properties. Its final conversion into blood, is consummated in the lungs.

2. By the *lymph* is meant a fluid, which is formed in another part of the absorbent system, the proper *lymphatics*. As these vessels spring from all parts of the body, and are supposed to be the principal agents of the decomposition of the organs, the fluid contained in them must consist partly of the *debris* of all the solids, as well as of various fluids, absorbed from the different cavities and surfaces of the system. These fluids, which are formed and deposited by a perpetual process of secretion, are subject to the action of the absorbents, so long as they remain in contact with any of the living tissues. Certain parts of them are imbibed by the lymphatics and blended with the molecules, detached from the decomposing organs, and both are elaborated together into the fluid called lymph. This fluid is conveyed by the lymphatics into the common trunk of the absorbent system, the thoracic duct, where it is mixed with the chyle, and both are immediately afterwards carried into the torrent of the venous blood near the heart. Like the chyle, the lymph contributes to repair the losses of the blood; but it is first subjected to the action of the lungs, in combination with the chyle and venous blood, and the whole compound fluid is converted by respiration into arterial blood. Like the chyle, too, the lymph bears a strong analogy to the blood in its composition and properties. These two fluids will be more particularly described hereafter.

II. The fluids formed out of the blood, will be described under the head of the secretions.

III. The BLOOD is the most important of the animal fluids. This name is given to the scarlet or purple fluid, contained in the arteries and veins and the cavities of the heart. It is apparently homogeneous, but is in fact a fluid of a very compound nature, consisting of various ingredients, possessed of peculiar chemical and physical properties. It has a specific gravity somewhat greater than that of water, a saline taste, and a faint animal odor.

It is well known, that the blood, soon after being drawn from the living vessels, loses its fluidity and concretes into a solid mass, and shortly after separates into two distinct portions. A yellowish transparent fluid oozes out of the coagulated mass, and when the process is completed, is found to constitute two-thirds, or three fourths of the whole. The coagulated part, which is of a red or dark brown color, is called the *crassamentum*, or *cruor* of the blood, and the fluid part, the *serum*.

The *coagulum*, or *cruor*, also, is found to consist of two parts; for, by ablution with water, it may be deprived of its red color, a fact, which proves that this color depends on the presence of a separate principle. When thus separated from the two other constituent principles of the blood, viz. the serum and the coloring matter, the coagulum appears as a soft solid, of a whitish color, insipid and inodorous, and of a greater specific gravity than water; and it sometimes presents a fibrous appearance, a circumstance from which it has received the name of *fibrin*. The coloring matter consists of minute globules of a red color, soluble in water, and which are visible in the blood when viewed through a microscope.

At the moment of its coagulation, small bubbles of gas escape from the blood, which force a passage through the coagulum on their way to the surface.

The *serum* is a transparent liquid, of a light yellowish color, of a saline taste, and of the odor of blood. It owes its taste to the presence of earthy and alkaline salts, which it holds in solution. Besides these salts, it contains a free alkali, as is evident from its changing vegetable blue colors to a green. But the

property by which it is peculiarly distinguished, is that of becoming solid by exposure to heat. The temperature necessary to produce this effect, must be as high as 160° F. At this temperature, serum becomes a white opake solid, of a firm consistence, resembling the coagulated white of an egg. It preserves its property of coagulating, even when diluted with a large quantity of water. Several other agents, besides heat, are capable of coagulating serum, as the mineral acids, alcohol, and some of the metallic salts. The action of the galvanic pile, also, coagulates it, and at the same time developes in it globules, which have a strong analogy to those of the blood. The coagulation of serum has been differently accounted for. By some chemists, it has been referred to the abstraction of its free alkali. Serum is a compound of albumen and soda, the latter of which is supposed to maintain the albumen in a liquid state. All agents, therefore, which are capable of abstracting the soda from the albumen, it is supposed, may indirectly cause it to coagulate, by removing the force which overcame its cohesive attraction. If we suppose the albumen to be kept in solution by means of the soda, it will be easy to understand, why acids and alcohol coagulate serum. The action of heat is a little different. On the application of heat, the equilibrium of affinities, by which these elements are held together, is deranged; and the soda, which before was in a state of chemical combination with the albumen, is transferred to the water, while the albumen is left to assume a solid form.

The natural color of the serum, is liable to be changed by the presence of accidental substances. In jaundice, it is of a deep yellow color, which is derived from an impregnation with bile. It also acquires a yellow color, in persons who have been taking rhubarb. In blood drawn from a person, who has recently eaten a hearty meal, the serum has been found to exhibit the color of turbid whey, owing, it is supposed, to the presence of chyle. In some cases it has been observed of a white color, like cream, and sometimes has been found to contain globules. This appearance has been

observed in the blood of persons, whose digestive organs were disordered, and who had been subject to sickness, vomiting, and bad appetite.

Berzelius and Marcet have, each, analyzed the serum of the blood, with the following results:

Berzelius.		Marcet.	
Water,	905.0	Water,	900.00
Albumen,	80.0	Albumen,	86.80
Lactate and impure phosphate of soda,	4.0	Extractive matter,	4.00
Hydrochlorate of potash and soda,	6.0	Hydrochlorate of potash and soda,	6.60
Impure soda,	4.0	Sub-carbonate of soda,	1.65
Loss,	1.0	Sulphate of potash,	0.35
		Earthy phosphate,	0.60
	1000.00		1000.00

A more recent analysis of serum by Le Canu, does not differ materially from the two former, except in the discovery of two new principles in this fluid; one a fatty, crystallizable matter; the other, an oily substance.

The *coagulum* or *cruor* of the blood, is composed essentially of fibrin and coloring matter. When freed from the coloring matter, fibrin is a soft solid, of a whitish color, without smell or taste, insoluble in water, not affecting the blue vegetable colors, and containing about four-fifths of its weight of water. Exposed to the air, it becomes dry, semi-transparent and brittle; and if in this state, it be plunged into water, it gradually absorbs as much as it has before lost by desiccation, and resumes its former properties. By distillation, it furnishes a large quantity of carbonate of ammonia, and a voluminous charcoal, which is very difficult to incinerate, and which leaves a residue containing a good deal of phosphate of lime, a little phosphate of magnesia, carbonate of lime and carbonate of soda.

One hundred parts of fibrin are composed of

Carbon,	53.360
Oxygen,	19.685
Hydrogen,	7.021
Azote,	19.934

Fibrin is considered by some chemists, as a mere modification of albumen. It is the basis of muscular flesh. It possesses the power of spontaneous coagulation, and the blood owes its property of coagulating to the presence of this principle.

The remaining constituent of the blood is the *red globules*. When examined by the microscope, the blood presents the appearance of a fluid, holding in suspension minute particles of a spheroidal figure. According to some observers, these consist of a solid nucleus or central part, surrounded by a vesicle, which contains a fluid. It appears that the blood of all animals contains globules. These differ in shape and size in the different species of animals. In the human species and the mammalia, in some of the fishes, in many of the mollusca, and in insects, they are round; in birds, in the amphibia, and in many of the fishes, they are of an elliptical shape. In the human blood, the diameter of the globules is variously estimated by different observers; the estimates varying from one-seventeen hundredth to one-six thousandth part of an inch. Perhaps their diameter may be assumed at about one-four thousandth of an inch.

The latest microscopical observations on the globules of the human blood, represent them as circular, flattened bodies, having a depression in the centre; consisting of a central nucleus with an external envelope of a red color.

Raspail considers the globules as composed of albumen, which has been dissolved in the serum of the blood by the aid of some menstruum, and is afterwards precipitated from it, by its neutralization, or by evaporation. To illustrate their formation, he states that, if a certain quantity of the white of eggs be put into an excess of concentrated hydrochloric acid, the albumen will at first coagulate and become white, but will afterwards dissolve in the acid, and assume a violet color, which subsequently changes to a blue. If the acid be then decanted, or suffered to evaporate, a white powder will be precipitated, which, when

viewed through a microscope, presents the appearance of very small spherical particles, of the same size with the globules of the blood, and which might easily be confounded with them. The number of the globules, he observes, will vary according to the quantity of the menstruum which evaporates in a given time, and many other circumstances.

The appearance of the central nucleus in each globule, he considers as, in most cases, the effect of an optical illusion; but that which is observed in the blood of frogs, he supposes to be owing to the successive solution of the different layers of the albuminous globule, in the water in which they are diffused in making the experiment. As the external layers of the albuminous globule, are the first to imbibe the water, they acquire a less refractive power than the central layers, which hence present a more opaque appearance than the external. When the most external layer is wholly dissolved, the next undergoes the same change, and so on till the globule is entirely dissolved and disappears.

The chemical relations of the globules, according to Raspail, are identical with those of albumen. They are soluble in water, in ammonia, in the acetic, and concentrated hydrochloric acids; and are coagulable by other acids, by heat, and by alcohol.

Arterial blood contains a greater number of globules than venous. The blood of birds, also, contains more than that of any other class of animals. The mammalia, in this respect, stand next to birds; and the blood of carnivorous animals appears to possess a greater number of globules than that of the herbivorous. In general, the quantity bears a certain relation to the degree of heat possessed by animals; the cold-blooded animals being those, whose blood contains the smallest proportion.

According to Treviranus and some other physiologists, the globules of the blood possess the faculty of spontaneous motion. Treviranus, with the assistance of a microscope, observed two kinds of motion in the

blood while flowing from the veins of a living animal. One consisted in a whirling or rotatory motion of the globules, while the other manifested itself by a kind of tremulous contraction of the whole coagulum. According to Copland, Professor Schultz of Berlin has more recently confirmed the fact respecting the intestine motion of the globules, which, as he asserts, move on spontaneously, keeping at a distance from one another, and surrounded by envelopes of coloring matter. This power of the globules, Copland attributes to the influence exerted by the ganglial nerves, which are plentifully distributed on the coats of the vessels. Another force, which Copland supposes to act upon them and to influence their motions, is the attraction exerted by the different tissues, with which they are brought into contact, while circulating in the capillary vessels. The former of these forces keeps the globules in a state of constant motion and repulsion; the latter tends to bring them to a state of repose, and is exerted in the organic structures themselves, where the globules of the blood come into contact with them.

The coloring matter of the blood, sometimes called *hematosine*, is supposed by some to reside in the envelope of the red globules. By Brande it is considered as a peculiar animal principle, capable of combining with metallic oxyds.—He formed compounds of this coloring matter with oxyd of tin. But the best precipitants of it are the nitrate of silver and corrosive sublimate. Woollen cloths impregnated with either of these metallic salts, and dipped in an aqueous solution of the coloring matter of the blood, became permanently dyed. Berzelius and Engelhart attribute the color of the blood to the presence of iron, in some unknown state of combination.

The coloring matter is soluble in water. When dried and exposed to heat in contact with the air, it melts, swells up, and burns with a flame, leaving a coal of very difficult incineration. This coal burns with a disengagement of ammoniacal gas, and leaves

the one-hundredth part of its weight of ashes, composed of

Oxyd of iron, - -	55.0
Phosphate of lime and a trace of phosphate of magnesia,	8.5
Lime, - - -	17.5
Carbonic acid, - -	19.0

The coloring principle of the blood is supposed to be derived from respiration, because the globules of chyle and lymph, which are converted into blood by respiration, are destitute of it.

The analysis of the integral blood, according to Le Canu, presents the following results:

Water, - - - -	780.145	786 590
Fibrin, - - - - -	2.100	3.565
Albumen, - - - -	65.090	69.415
Coloring matter, - - - -	133.000	119.626
Crystallizable fatty matter, - -	2.430	4.300
Oily matter, - - - -	1.310	2.270
Extracted matter soluble in alcohol and water,	1.790	1.920
Albumen combined with soda, - -	1.265	2.010
Chloruret of sodium and potassium, alkaline phosphates, sulphates and sub-carbonates,	8.370	7.304
Sub-carbonate of lime and magnesia, phosphates of lime, magnesia and iron, per oxyd of iron, - - -	2.100	1.414
Loss, - - - - -	2.400	2.586
	1000.00	1000.00

The coagulation of the blood has been attributed to various causes, as, e. g. its cooling, on being drawn from the vessels, the contact of the air, rest, &c. None of these causes, however, are sufficient to produce this effect. Hewson froze fresh blood by exposing it to a low temperature, and afterwards thawed it. It first resumed its fluidity, but afterwards coagulated in the usual manner. It has also been ascertained by experiment, that blood will coagulate, when deprived of the contact of the air, and subjected to agitation. In the exhausted receiver of an air-pump, its coagulation is even accelerated. Coagulation is influenced by the rapidity with which the blood flows from the body. According to Scudamore, blood slowly drawn from

a vein, coagulates more rapidly than when taken in a full stream. Exposure to oxygen gas accelerates it.

During the coagulation of the blood, the temperature of the mass is said to rise. Dr. Gordon estimated the rise of the thermometer at six degrees. Dr. Davy, however, regards the increase of temperature from this cause, as very trifling.

Certain saline substances, as, a saturated solution of common salt, muriate of ammonia, nitre, or a solution of potash, prevent a coagulation of the blood; while alum, and the sulphates of zinc and of copper, promote it. Electricity, according to Scudamore, does not prevent coagulation. Blood, subjected to electric shocks, was found to coagulate as quickly, as that which was not electrified; and the blood was always found coagulated in the veins, in animals killed by powerful galvanic shocks.

Raspail accounts for the coagulation of the blood, by referring it to the neutralization, or evaporation of some menstruum, which maintained the albumen in a liquid state. This menstruum he supposes to be soda and ammonia. On this principle, he observes, the spontaneous coagulation of the blood, presents no insuperable difficulty. For, the carbonic acid of the atmosphere, and the carbonic acid, which is formed in the blood itself by the absorption of oxygen, combines with and saturates the menstruum of the albumen, which is consequently precipitated in the form of a coagulum. The evaporation of the ammonia, which is another menstruum of the albumen, and that of a part of the water of the blood, liberates another portion of dissolved albumen, and increases the quantity of the coagulum.

Raspail, on the same principle, accounts for the precipitation of the albumen in the form of the globules of the blood, which he considers as identical with albumen. The absorption of the aqueous part of the blood, by the tissues nourished by it, and perhaps the saturation of the alkaline menstruum of the albumen, by the residue of nutrition constantly passing into the blood from the same tissues, occasion a regular pre-

cipitation of albumen in the blood, in the form of small globules.

The coagulation of the blood, however, is regarded by the most enlightened physiologists, as a vital phenomenon, and as not depending on any physical cause. "The blood is supposed either to be endowed with a principle of vitality, or to receive from the living parts, with which it is in contact, a certain vital impression, which, together with constant motion, counteracts its tendency to coagulate."

Copland ascribes the coagulation of the blood principally to the agency of the red globules, resulting chiefly from the loss of the vital motion which these globules possess in the vessels, and that of the attraction existing between the coloring envelopes and the central globules, contained in them. This attraction ceases soon after the blood is removed from the veins; and the central bodies, freed from the colored envelopes, are left to obey the attraction, which tends to unite them; and in uniting, they form a net-work, in the meshes of which the coloring matter is entangled; and the phenomena of coagulation are thus produced.

The blood furnishes the elements of nutrition to all the tissues and organs of the body; and recent analyses of this fluid have ascertained in it the presence of many of the peculiar forms of animal matter, of which the organs are composed. Vauquelin discovered in the blood, a considerable quantity of a fatty substance, which was at first supposed to be fat, but which was afterwards ascertained by Chevreul, to be the peculiar substance of the brain and nerves. It differs from fat and all other substances of the same nature, in containing azote.

Prevost and Dumas demonstrated the existence of urea, a peculiar animal matter found in the urine, in the blood of animals, whose kidneys had been extirpated. Cholesterine, and some of the other elements of the bile, have been discovered in the serum of the blood. The fibrin, which exists in this fluid, is identical with the muscular fibre; its albumen is the

basis of a great number of membranes and tissues: the fatty substance, before mentioned, combined with albumen and ozmazome, forms the nervous system; and the phosphates of lime and magnesia, which exist in the blood, constitute a great portion of the substance of the bones.

CHAPTER X.

Chemical Analysis of the Organization.

It has already been observed, that organized matter consists of two classes of elements, viz. one *chemical*, the other *organic*. The chemical, are the ultimate elements, into which organized substances may be reduced by destructive analysis; as, oxygen, hydrogen, carbon, azote, &c. The organic, are the proximate elements, which are formed out of the ultimate, not by the chemical powers of matter, but by the operation of the organic forces. These are albumen, fibrin, gelatin, ozmazome, &c. All animal matter may be analyzed proximately into these elements. The chemical forces tend to destroy these forms of matter, and to reduce them to the ultimate elements.

The Ultimate Elements.

The ultimate ponderable elements of animal matter may be divided into *non-metallic* and *metallic* substances.

I. The non-metallic elements are oxygen, hydrogen, carbon, azote, phosphorus, sulphur, chlorine, and fluorine. (Berthold.)

II. The metallic elements are, 1. The bases of the alkalies, viz. potassium, or kalium, sodium, and calcium. 2. The metallic bases of some of the earths, viz. magnesium, silicium, and aluminum. 3. The ponderous metals, iron, manganese, and copper.

Of these, the four first of the non-metallic elements, viz. oxygen, hydrogen, carbon, and azote, exist in vastly the greatest proportion, and perhaps may be considered, as the only essential elements of animal matter.

Oxygen enters very largely into the composition of animal matter. It is a constituent part of all the fluids and solids of the body. It is an essential element of all the proximate elements, for these may be all divided into organic oxyds and acids. In combination with hydrogen, it forms the watery basis of all the fluids, which constitute, as it has been computed, nine-tenths of the whole weight of the body. In union with carbon it forms carbonic acid, which exists in the blood, and is exhaled abundantly from the lungs in respiration, and from the skin. With phosphorus it forms the phosphoric acid, which exists largely in the bones in combination with lime, and is one of the constituents of healthy urine. With the metalloids it forms potash, soda, and lime. It also enters into the composition of the organic elements, as albumen, fibrin, gelatin, and mucus. The oxygen, which exists in the body, is derived partly from the food and drink, and partly from respiration. It is eliminated from the system by all the excretions, particularly by sweat, urine, and respiration.

It is remarkable, that in certain fishes, the air contained in the swimming vesicle, is pure oxygen gas. This is the case with the fishes, which live near the bottom of the water, and swim near the ground.

Hydrogen is another principle which exists in all the fluids, and several of the solids of the body. It constitutes one element of the water basis of the fluids. It predominates in venous blood, as oxygen does in arterial. It exists largely in the bile; is one of the elements of fat and oil; and is often developed in a

gaseous form in the intestinal canal, in enfeebled states of digestion. Combined with chlorine, it forms the hydrochloric acid, which exists in many of the animal fluids, in combination with soda. Hydrogen is introduced into the system by the aliments, and is eliminated by cutaneous and pulmonary exhalations, by the excretions of the kidneys, alimentary canal, and liver. In the process of putrefactive decomposition, it combines with sulphur, and sometimes with phosphorus, forming, with them, two fetid gases the sulphuretted and phosphuretted hydrogen.

Carbon.—This element abounds in the vegetable kingdom, but is also found largely in animal substances. It is one of the elements of animal oil or fat, and of the quaternary animal oxyds, albumen, fibrin, gelatin, and mucus. It exists largely in the bile, and in venous blood. Most animal substances by combustion develope a considerable quantity of carbon. It is received by the aliments, and is eliminated by respiration, by cutaneous transpiration, and by the secretion of the liver. It is constantly developed by the processes of life, accumulates in the venous blood, and is discharged from it principally by respiration.

Azote.—This principle exists largely in animal matter, and is regarded, as one of its principal chemical characteristics. It is true, however, that a few plants contain it, particularly the mushroom tribe. It abounds, also, in the pollen of plants, and in the vegetable principle, gluten, and is one of the elements of the vegetable alkaloids, quinine, strychnine, &c. But, it exists almost universally in animal substances, and may be regarded as one of its essential elements. All the organic elements of animal matter contain azote; but it exists most abundantly in fibrin, and, consequently, in the muscular flesh, which is formed principally of this element. The substance of the brain and nerves, contains a less proportion of azote. The peculiar smell of burning animal matter is owing chiefly to the presence of this principle. In the putrefaction of animal substances,

the azote, disengaging itself from the other elements, combines with the hydrogen, forming a binary compound, *ammonia*, which is one of the characteristic results of animal decomposition.

Azote is received into the system, chiefly with the food, particularly with that which is derived from the animal kingdom, and from the leguminous plants, and the seeds of the *cerealia*. It is, also, believed to be introduced into the blood by respiration, in which, it appears to be ascertained, there is an absorption of azote. Its discharge from the system is effected, principally, by the secretion of the kidneys, as it exists largely in healthy urine; but partly by respiration, in which there appears to be an exhalation, as well as absorption, of azote. It always exists in combination with other elements in the animal system, except in the vesicle of certain fishes which swim near the surface of the water, in which it is found in a pure state.

Of these four essential elements of animal matter, three, when in an uncombined state, are aëriform bodies; and the effort which they make, as they exist in animal substance, to abandon the solid form, and resume their natural state as gases, an effort which is increased by the external heat, to which animal substances are exposed, and by their own organic heat when in a living state, promotes the tendency to decomposition of animal matter.

Phosphorus.—This principle exists both in animal and vegetable substances, but more abundantly in the former. It is present in the blood and the brain, and, indeed, in nearly all parts of animal bodies, but is contained in the greatest proportion in the bones, combined with oxygen, with which it forms phosphoric acid. It always exists in combination, generally in the state of phosphoric acid. It is evacuated chiefly by urine, which contains a considerable quantity of phosphoric acid, some of it free, and some in combination with bases. During animal decomposition, a part of the phosphorus combines with hydrogen, forming the fetid gas, phosphuretted hydrogen. The phosphorescence of putrefying animal matter, is supposed to

be owing to some inflammable compound of this kind. The extraordinary phenomenon of the spontaneous combustion of the human body, has been attributed, by Treviranus, to an accumulation of phosphorus in the system, owing to some obstacle to its regular excretion by the kidneys and other outlets. The body, it is supposed, may at length become so highly charged with it, as to be rendered extremely combustible.

Sulphur.—This is another principle of animal substances, which always exists in combination with other elements, as soda and potash. It exists particularly in albumen, and in the hair and nails, and also in muscular flesh. It is extricated in the intestines in combination with hydrogen, and then discharged from the system. It also, sometimes, passes off by cutaneous transpiration. The fetor of foul ulcers is occasioned partly by an evolution of sulphuretted hydrogen; and the same gas is supposed by some to be the vehicle of infection in the hospital gangrene.

Chlorine exists in most of the animal fluids in combination with hydrogen, forming the hydrochloric acid. This is present in a free state in the gastric fluid, and in combination with soda and potash in the blood and bile. It exists, also, in the urine, in the sweat, milk, saliva, synovial fluid, &c.

Kalium or *Potassium*, exists very sparingly in the system, and always in combination with oxygen, i. e. in the state of *potash*. Combined with muriatic acid, potash is present in the blood, and several of the secreted fluids, as the bile, urine, sweat, milk, &c. In combination with the phosphoric acid, it exists in the brain. It is much more abundant in plants than animals.

Sodium.—This metalloid, in combination with oxygen, is much more abundant in animal substances than *kalium*. As soda, it exists in the blood, mucus, saliva, bile, muscular flesh, bones, milk, and other animal substances, in combination with the carbonic, phosphoric, sulphuric, muriatic, and lactic acids. It is more common in animals than in plants.

Calcium, in the form of lime, exists largely in the bones, and sparingly in the muscles and brain. It is

generally combined with the phosphoric acid, as in the bones, but sometimes with the carbonic acid, forming the phosphate and carbonate of lime.

Silicium is found, though very sparingly, in some kinds of animal matter. It exists as silex in the human hair, and in the urine.

Magnesium exists in animal and vegetable substances, especially in bones, and in some animal fluids. In combination with phosphoric acid, it is found in the blood, in the substance of the brain, and in human milk.

Iron.—This metal is pretty extensively diffused in animal bodies; especially in the blood of red-blooded animals, and in the *pigmentum nigrum*. In what state it exists in the blood, is not known. It is supposed by some physiologists, in some indeterminate state of combination, to form the coloring principle of the red globules of the blood.

The Organic or Proximate Elements.

The proximate principles of animal matter, are formed by various combinations of the ultimate elements, by the influence of the vital or organic forces. These principles are, for the most part, quaternary compounds of oxygen, hydrogen, carbon, and azote. Some of the acids found in animals, form an exception to this general fact, being formed of only three elements.

The organic elements may be divided into two classes, viz. *acids* and *oxyds*. In addition to these, vegetables possess a peculiar kind of proximate principles, which are not found in animals. These are the recently discovered vegetable alkalies.

1. The organic *acids* found in the human system, are the *acetic*, the *oxalic*, the *benzoic*, and the *uric*. The three first are common to the animal and vegetable kingdoms, and consist of three elements only, viz. oxygen, hydrogen, and carbon. The *acetic*, called also, the *lactic* acid, exists in milk, urine, and in many

other animal fluids. The *oxalic* exists in some of the urinary calculi, particularly the mulberry calculus. The *benzoic* acid has been discovered in human urine.

The *uric* acid consists of four elements, oxygen, carbon, hydrogen, and azote. It is a constituent part of human urine, and of that of many other animals, as birds, reptiles, and insects.

2. The organic *oxyds* are numerous, both in the vegetable and animal kingdoms, and differ widely from one another in their properties. Some of them consist of three elements, oxygen, carbon, and hydrogen; others, of four, containing azote in addition to the three former.

The *ternary* oxyds found in the animal kingdom, are *sugar*, *resin*, and *fixed* and *volatile oils*.

Of *sugar*, there are two varieties found in the human system. One, the *sugar* of milk; the other, a morbid product, existing in the urine of persons affected with diabetes.

The *sugar of milk* is obtained from the whey, by evaporating it to the consistence of syrup, and allowing it to cool. It is afterwards purified by means of albumen and crystallizing it again. In many respects it differs from the sugar of the cane, though possessing a sweet taste. It is not susceptible of the vinous fermentation; and may be converted by the action of the nitric acid, into the *saccholactic* acid; a property in which it differs from every other kind of sugar.

The *sugar of diabetes* exists in the urine of persons affected with this disease. It may be obtained by evaporating diabetic urine to the consistence of a syrup, and keeping it in a warm place for several days. In its properties and composition it appears to be identical with vegetable sugar.

A peculiar *resin* exists in the bile.

Of *fixed oils*, fat and the marrow of the bones, are examples.

Volatile oils are found in some of the inferior animals, but not in man.

The *quaternary* compounds, formed of oxygen, carbon, hydrogen, and azote, are the most important

proximate principles of animal matter. Among those which are most generally diffused, and which enter more or less into the composition of almost all animal bodies, are *albumen*, *fibrin*, *gelatin*, *mucus*, and *ozmazome*. Besides these, there are several others which are less common, as *caseine*, *urea*, *hematine*, the black matter of the eye, *cholesterine*, *picromel*, &c.

The first of these, *albumen*, is, of all substances, the most generally diffused in the animal economy. It exists both in a liquid and in a solid form. Combined with a greater or less proportion of water and a little saline matter, it constitutes the white of eggs, from which it derives its name, *albumen;* it forms, also, the serum of the blood, the aqueous fluid of the cavities and cellular tissue, and the fluid of dropsies. It constitutes the principal part of the synovial fluid, and it exists in the chyle and lymph. It forms the fluid of blisters and burns, and that which is contained in the hydatid. It is a colorless, transparent substance, without taste or smell, coagulable by heat, by alcohol, ether, concentrated sulphuric acid, some of the metallic salts in solution, and an infusion of tannin. Exposed to a certain degree of heat, (about 160 F.) it coagulates into an insoluble mass.

Solid albumen is a white, tasteless, elastic substance, insoluble in water, alcohol and oils, but readily dissolved by alkalies. It constitutes the basis of the substance of the nerves, and brain, and is contained in several of the tissues of the body, as, e. g. the skin, glands and vessels. It exists in the hair and nails; and morbid growths and tumors are composed principally of it.

Albumen is composed of

Carbon,	52.883	or	17 equivalents.
Oxygen,	23.872		6 do.
Hydrogen,	7.540		13 do.
Azote,	15.705		2 do.

It also contains a small quantity of sulphur; since it blackens silver, and, in a state of decomposition, exhales sulphuretted hydrogen gas. The physiological property, which corresponds with albumen, is *sensibility.*

Fibrin is a principle, which enters largely into the composition of the blood, chyle, and lymph, and is the basis of muscular flesh. It possesses the property of spontaneously coagulating, and it is owing to the presence of fibrin that the blood coagulates, when drawn from the living vessels. In its coagulated state, fibrin is a solid, whitish substance, of a fibrous appearance, and may be easily drawn into threads. It is destitute of smell and taste, and insoluble in water. It may be obtained by stirring fresh blood with a stick until it coagulates, and then washing the fibres which adhere to the stick, with cold water, so as to dissolve out the red globules. In its chemical composition and many of its properties, it resembles albumen, but differs from it, in coagulating at all temperatures.

Fibrin is composed of

Carbon,	53.360	or	18 equivalents.
Oxygen,	19.685		5 do.
Hydrogen,	7.021		14 do.
Azote,	19.934		3 do.

From this analysis it appears, that fibrin is more highly azotized than *albumen.* The physiological property which corresponds to it, is *irritability.*

Gelatin is another element of almost all the solid parts of the body; but, what is remarkable, it exists in none of the fluids. It is a substance, distinguished from all other animal principles by its readily dissolving in warm water, and forming a bulky, tremulous solid on cooling. When dried, it forms a hard, semi-transparent, brittle substance, with a shining fracture. One part of gelatin dissolved in one hundred parts of warm water, becomes solid on cooling, forming a hydrate of gelatin.

The well known cement, glue, which is prepared from the skins and hoofs of animals, by boiling them in water, and evaporating the solution, is an impure gelatin. The ising-glass of commerce, prepared from the sounds of the sturgeon, is a very pure species of this principle.

Gelatin forms the basis of the cellular tissue and its modifications, and exists in the skin, cartilages, ligaments, tendons and bones. As it is not present in the blood, nor indeed in any of the animal fluids, it is a question by what means it is formed in the system. This question we have at present no sufficient means of answering. It is, probably, like fibrin, a mere modification of albumen. It is composed of

Carbon, - - -	47.881
Oxygen, - -	27.207
Hydrogen, - - -	7.914
Azote, - -	16.998
	100.00

The property which corresponds to gelatin in the system is *animal elasticity.*

Osmazome.—This is another element, which is found in all the animal fluids, and in some of the solid parts of the body, as the brain and the muscular fibre. It exists in the flesh of most adult animals. It is a reddish brown substance, of an aromatic smell, and of a strong and agreeable taste. The flavor and smell of beef-soup are owing to the presence of osmazome. The strong taste of roasted meat, also, is supposed to depend on osmazome. It is distinguished from other animal principles by its solubility in water and alcohol, either cold or hot, and by not forming a jelly, when its solution is concentrated by evaporation. According to Orfila, it possesses no nutritious powers, but is tonic and stimulating.

By some physiologists, osmazome is regarded as a peculiar extractive matter of flesh; but by Berzelius

it is considered as a compound formed of a peculiar animal matter, combined with lactate of soda, and by Raspail, as an impure combination of albumen and acetic acid.

Mucus.—This is a secreted fluid, which lubricates the surface of the mucous membranes. In a solid state it enters into the composition of some of the hard parts of the body, which are destitute of sensibility, as the nails, hair, cuticle, and horny parts, which consist chiefly of inspissated mucus. The scales, feathers, and wool of different animals contain a good deal of mucus. The *rete mucosum* is supposed to be formed of compacted mucus. In union with water, mucus is a transparent, viscid, ropy fluid, without odor or taste. Nitric acid, at first, coagulates, but afterwards dissolves it. In its dry state it is insoluble in water. In hot water it imbibes so much of the fluid as to swell and become softened. The acids are its true solvents. It contains a good deal of azote.

Caseine.—This substance exists only in the milk of the mammiferous animals, and is obtained from this fluid after it has been coagulated. After the removal of the cream, the curd must be well washed with water, drained on a filter and dried; and it then constitutes the caseine. This principle derives its name from its being the basis of cheese. It is a white, insipid, inodorous substance, of a greater specific gravity than water, and is highly azotized, and very nutritious. When decomposed by fire, it yields a large quantity of carbonate of ammonia.

Caseine appears to have a strong resemblance to albumen, particularly in being coagulated by acids. It is composed of

Carbon, - - -	59.781
Oxygen, - -	11.409
Hydrogen, - - -	7.429
Azote, - -	21.381
	100.000

Urea is a matter, which exists in human urine and in that of quadrupeds. It may be procured by evaporating fresh urine to the consistence of a syrup, and gradually adding to it concentrated nitric acid, till it becomes a dark colored, crystallized mass. This is to be well washed with ice-cold water, and then dried by pressure between folds of blotting paper. The nitrate of urea is afterwards to be decomposed by a strong solution of carbonate of potash or soda. The solution is then to be evaporated almost to dryness, and the residue to be treated with pure alcohol, which dissolves only the urea. The alcoholic solution is afterwards to be concentrated by evaporation, and the urea is deposited in crystals.

The crystals of urea are transparent, and colorless, and without odor. They leave a sensation of coldness on the tongue like nitre, and have a specific gravity greater than water. Urea is soluble in water and alcohol. Though not distinctly alkaline, it has the property of uniting with the nitric and oxalic acids. It is very highly azotized.

It is composed of

Oxygen, - - -	26.40
Azote, - - -	43.40
Carbon, - - -	19.40
Hydrogen, - -	10.80
	100.00

The other quaternary oxyds are not of sufficient importance to be here particularly described.

CHAPTER XI.

Physiological Analysis of the Organization.

All organized beings, vegetable, as well as animal, are endued with the property of being affected by various external agents, and of being excited to action by them. All the manifestations of life in organized matter are the effect of impressions made upon it by external or internal agents, giving rise to vital reaction under the influence of this property. It is this power in the seed, the egg, and the germ, which, reacting against impressions made upon them by certain external circumstances, gives rise to a series of internal movements, by which they are gradually developed, and their organization assumes the variety, complication and form, demanded by the type of being, to which they respectively belong. This power, itself, assumes new properties or modifications in the different varieties of the organization thus developed; each one reacting in its own peculiar manner against the impressions made upon it; every fibre, every tissue, every organ possessing its own specific excitability, and manifesting its own mode of activity, when excited by appropriate impressions. Thus, the cellular tissue, the muscles, the nerves, the vessels, the bones, the organs of sense, enjoy, each their own peculiar species of excitability, according to the difference of structure and constitution bestowed upon them at their original formation. The alimentary canal is excited by the presence of food, and by its own secreted fluids. Every gland is solicited by its appropriate stimuli to secrete its peculiar product. The organs of sense are excited by certain external impressions, each in a mode peculiar to itself. The brain is roused to action by external

or internal impressions, conveyed to it by means of the nerves, and the muscles are excited to contraction, by excitations derived from the nerves. In short, all the solid parts of the living system are endued with this property, and are capable of exhibiting some modification of vital reaction, under the influence of external impressions of various kinds. Even the globules contained in the blood, and some of the other fluids, seem to be endued with this property; as their motions appear to be influenced by external excitations which act upon them.

This property of living matter assumes three principal modifications in the different solids and fluids, and may be analyzed into three distinct forces, viz. *sensitive*, *motive*, and *alterative*. The sensitive powers are *sensibility*, and its modifications; the motive, are *contractility*, and *expansibility* or *erectility;* the alterative, may be comprehended under the expression, *vital affinity*. These may be termed the physiological properties of the organization, which distinguish it in a peculiar manner from lifeless matter. In addition to these, living matter possesses certain *physical* properties in common with inanimate bodies, as *elasticity*, *extensibility*, *flexibility*, *imbibition*, and *evaporation*.

I. *Physiological* or *vital* properties.

1. The first of the physiological properties is *sensibility*, which is the exclusive attribute of the nervous system. It is peculiar to animals provided with nerves, and its office is to enable them to receive from the external world, or from their own organization, impressions of which they are conscious.

Sensibility presides over all our sensations, external and internal, and may be divided into two kinds, viz. *general* and *special*.

General sensibility animates the whole periphery of the body, the skin, and the origin of the mucous membranes. In the interior of the body, it exists in all the soft solids, and its office appears to be, to convey to the mind a knowledge of the wants of the system; and, in a pathological state, to apprize it, by means of the sensation of pain, of the disorders which exist in the organization.

Special sensibility is a property which is the basis of the relation existing between the organs of specific sensation, and the peculiar stimulants which act upon them. Thus the eye is endued with specific sensibility to light; the ear, to the impressions of sound; the palate, to tastes; &c.

Sensibility, both general and special, has a common centre, which is the *brain*. This organ is the great focus of sensation, to which all impressions must be transmitted, before they can be felt. Its own action is indispensable to sensation; for, if it be rendered, by any cause, incapable of reacting upon the impressions transmitted to it from the senses, no sensation is excited by them. It is here, also, that sensation elaborated by the intellect, gives rise, directly or indirectly, to all the modes of perception and thought.

According to Bichat and some other physiologists, there is another species of sensibility, which does not require the intervention of the brain, and which has received the name of *organic*. It resides in the, organs where it is called into exercise, and its centre is supposed to be the *great solar plexus*. Its manifestations are independent of the brain, never, at least in the normal state, invoking the assistance of this organ, nor giving rise to the feeling of consciousness. According to Bichat, the stomach may be said to be sensible to the presence of food; the heart, to the stimulus of the blood; the excretory vessels, to the presence of their respective contents; &c.; but in all these cases, which are examples of *organic* sensibility, the feeling is either confined to the organ, where it is excited, or it perhaps extends to the great ganglionic centre. It is not propagated to the brain, and is not accompanied with the consciousness of the individual.

It is evident, however, that the existence of this species of sensibility stands on very different grounds from those on which the former rests. We have the highest possible evidence of the existence of cerebral sensibility, in our own feelings and consciousness; whereas that of organic sensibility is a mere hypothesis

which we are induced to make, to enable us to explain certain phenomena, which appear to imply it.

If, however, we admit of the existence of this species of sensibility, we may divide the faculty into two kinds, viz. *cerebral*, and *organic* or *vegetative*. The first has a common centre, the *brain*, the intervention of which is indispensable to its manifestations, and its exercise is necessarily accompanied with consciousness. The second, also, has a common centre, viz. the *solar plexus*, is independent of the brain, and its exercise conveys no notice to the mind.

Cerebral sensibility is displayed in all our sensations and perceptions, external and internal; *organic* or *vegetative*, in the processes of digestion, circulation, secretion, absorption, nutrition, &c.

In some parts of the system, according to Bichat, the presence of those fluids or solids, with which these parts are usually in contact, produces only organic impressions, which, in a healthy state, never give rise to animal sensation. This is the case with the mucous membranes, lining passages which open to the external air. The presence of the fluids, secreted by these membranes, and the transit of the substances to which they are designed to give passage, in general, excite little sensation, of which we are conscious. The impressions, which these substances produce, are confined to the surface, with which they are in contact. But, if foreign bodies be brought into contact with them, cerebral sensation is immediately developed, and the individual becomes conscious of the impression. There are, also, certain parts of the body, which in a healthy state appear to be wholly destitute of *cerebral* sensibility, though their growth and nutrition, in common with that of other parts of the system, prove that they possess *organic*. These are the bones, cartilages, and ligaments, parts which are wholly destitute of feeling in a healthy state. But when they are affected with disease, animal sensibility is sometimes developed in them, and they become the seats of acute pain. The alimentary canal possesses cerebral sensibility at its two extremities, but organic, in the intermediate parts.

The peculiar seats of cerebral sensibility, are the organs of animal life, or of *relation*, as they are termed; as the skin, and the organs of sense, the nerves, muscles, and, in a less degree, the membranes and viscera. All the solid parts, without exception, are endued with organic sensibility, for all parts are nourished and grow.

2. *Contractility*, or the faculty by virtue of which a living part contracts, is the principal *motive* force of the system. All the motions of the body have been sometimes traced up to this property, though there appears to exist a peculiar motive power in the system, which displays itself in the dilatation or *erection* of parts, and which cannot without difficulty be referred to contractility. Broussais, however, has attempted to trace up not only all the manifold movements, of the system, but, even all the vital manifestations whatever, to this single property of contractility.

Living animal matter has the faculty of condensing itself, under the influence of certain external impressions. In a single fibre, this condensation manifests itself in a shortening of the fibre, or the approximation of its two extremities.

This tendency to contraction exists in various degrees in different kinds of animal matter. The organic element which possesses it in the most eminent degree, is fibrin. Hence those tissues, which possess the greatest degree of contractility, contain the largest proportion of this principle. Accordingly, the muscles which are peculiarly distinguished by their power of contraction, are composed almost wholly of fibrin. It is, perhaps, owing to this property that the fibrin, which is maintained in a fluid state in the blood when moving in the living vessels, becomes coagulated and condensed, as soon as the blood ceases to move. In the living state, the molecules of fibrin are kept in a state of mutual repulsion, perhaps by the vital influence of the walls of the vessels, in which they move. But, as soon as they are withdrawn from this influence, either by the death of the vessels, or by the removal of the blood from the body, the particles of

fibrin approach one another by virtue of this property of attraction, and unite together into a concrete mass.

When organized into muscles, fibrin contracts on the application of certain stimuli, either transmitted by nerves from the brain, or applied directly to them.

Those tissues, which are formed chiefly out of gelatin or albumen, and are wholly destitute of fibrin, as the membranes, vessels, cartilages, &c., possess a certain kind of contractility, i. e. they have the faculty of reacting against any distending force, and of recovering their former dimensions when this is removed; but they have not been supposed to be contractile in the same sense as the fibrinous tissues, i. e. to possess the power of contracting on the application of stimuli; an opinion, however, which is not strictly correct.

Vital contractility exists in two modifications.

One of them requires, for its exercise, the influence of the brain, which is transmitted by means of nerves to the organs, in which it is called into action, viz. the locomotive and vocal muscles. All the voluntary motions of the body, and all the muscular exertions employed in the various acts, which we consciously perform, are examples of the exercise of this power. The mechanical movements of respiration, those subservient to the voice and to speech, with all the numerous gestures, and motions of the body, have their foundation in this power. Its exercise is under the immediate control of the will, and is attended with the consciousness of the individual. It may be termed *cerebral* contractility, because the influence of the brain is necessary, in the normal state, to excite it to action.

The absence of cerebral contractility in a part naturally possessed of it, is called paralysis; its morbid excess or exaltation, spasm or convulsion. By Bichat this power is denominated *animal contractility;* by some others, *locomotility.*

The second modification of contractility is termed *organic,* because it is a property which belongs to, and animates every part of the organization. It is independent of the brain, and its manifestations result from the immediate excitation of the organs themselves,

from stimuli applied directly to them. Its exercise is wholly uninfluenced by the will, and is not accompanied with consciousness.

Organic contractility has been subdivided into two kinds, *sensible* and *insensible*, according as its phenomena are manifest, or obscure and latent.

Thus certain organs, as the heart, the stomach, the bladder, and the uterus, possess an inherent power wholly independent of the brain or will, of contracting in a manifest and obvious manner under certain circumstances, i. e. the application or presence of peculiar stimuli. The effect is wholly independent of the will and consciousness of the individual. Aliments excite contraction of the stomach and bowels; the presence of urine stimulates the bladder to contract; the full grown fœtus excites the uterus; the stimulus of the blood, the heart, &c.

This species of organic contractility is a prominent attribute of the hollow muscles, or those which are placed out of the jurisdiction of the brain, as the heart, the stomach, intestines, &c.; but it is not exclusively confined to them. It exists in the reservoirs and canals belonging to some of the secreted fluids, and according to some physiologists, in the skin and cellular membrane, tissues which are not muscular in their structure, and contain no fibrin, but consist almost wholly of gelatin.

Insensible organic contractility.—This property is of the same nature as the preceding, and differs from it chiefly in the circumstance, that its effects are much less conspicuous. In fact, the very admission of it as a distinct property, is rather a deduction of reason, than the immediate result of observed facts. That is, we are compelled to resort to the supposition of a force of this kind, in order to account for many of the vital phenomena, especially the motion of the blood in the capillary system of the circulation; that of the absorbed fluids in the lymphatics and lacteals; and the passage of the secreted fluids through the fine canals of the glands which prepare them. The phenomena hardly admit of an explanation, without resorting to

the supposition of a power of contraction in the walls of the canals or vessels, which are the seats of these phenomena. But, as its effects are not of a manifest kind, like the contractions of the heart, or stomach, or bladder, it may be termed *insensible organic contractility.*

The motion of the blood in the two extremes of the circulating system, may serve as an illustration of these two kinds of organic contractility, sensible and insensible. In the larger vessels the blood is propelled by the sensible organic contractility of the heart. This force pushes it forward as far as the fine ramifications of the arterial system, termed the capillary vessels, where the action of the heart is probably little felt. The motion of the blood, however, still continues, though it is propelled by other causes than the action of the heart. It is forced on by the *insensible* contractions of these hair-like vessels themselves, until it passes into the radicles of the veins.

This insensible organic contractility exists in animals destitute of a heart, or central moving power. The motions of their fluids must be maintained by a propulsive force of this kind, existing in the vessels themselves. A similar force exists in the vessels of plants, and the motions of their fluids are maintained by it. In the animal body, the seats of this power are the capillary vessels of the circulation, the lymphatic system, including the lacteals, and the fine canals by which the secreted fluids pass out from the place of their formation.

These two modifications of organic contractility are regarded as, at bottom, the same, but differing in their manifestations according to the structure of the part to which they are attached. They have been ingeniously compared to the hour and minute hands on the dial of a clock, which are both moved by the same power; yet the motion of one is insensible to the eye, while that of the other is distinctly visible.* They possess one character in common, viz. that the effects

* Diction. de Medicine.

which they produce, are not within the jurisdiction of the brain, and are wholly independent of the will. These effects are the result of various stimuli applied directly to the organs, which are the seats of them. Thus, the blood, the aliments, the urine, put in play respectively the organic contractility of the heart, the stomach, the bladder; the bile, the tears, the lymph, that of the excretory ducts of the liver, the lachrymal ducts, the lymphatics, &c.

Expansibility.—Another of the motive forces is *expansibility*, a property, by the exercise of which a part becomes the seat of a turgescence, or active dilatation. This power differs from elasticity, which is purely a physical property, in not requiring the application of an expanding force. It is directly opposed in its nature and effects to the faculty of contractility.

The property of expansibility is exemplified in the phenomena of vital turgescence in the *erectile tissues*, as the male and female organs of generation, both external and internal, which become turgid, and gorged with blood, under the influence of venereal desire; and in the nipple, which is similarly affected in the act of suckling. The same property is manifested in the skin, and the subcutaneous cellular tissue. Thus the face is said to swell with pleasure, the neck, to become tumid with anger; the ends of the fingers experience a degree of erection in the act of touching, and the papillæ of the tongue in tasting. In a state of inaction these papillæ are small, soft, pale, and indistinct. In a state of erection, on the contrary, they are enlarged, erect, red and turgid with blood. In fact, any of the soft solids, which are furnished with blood-vessels, may become the seat of this phenomenon. Any of them may become the focus of a fluxion of blood, if subjected to irritation. Thus, the internal membranes, as the serous, mucous, and synovial, when irritated, become turgid with blood, which accumulates in their vascular tissue. This is particularly exemplified in the gastric mucous membrane, when excited by the presence of aliment; and in the serous and synovial membranes, when

exposed to the air, or subjected to any kind of irritation. The glands exhibit similar phenomena under the same circumstances; and even the muscles and nerves, and other parts provided with vessels, become turgescent with blood, when laid bare, and subjected to irritation.

The parts which exhibit this phenomenon in the most conspicuous degree, as the organs of generation, and the nipples, are composed of a tissue of blood-vessels, interlaced with numerous ramifications of nerves.

The erectile tissues are sometimes developed accidentally, or by disease. Aneurism by anastomosis is of this description. Hemorrhoidal tumors, also, sometimes present all the characters of the accidental erectile tissues.

The dilatation of the heart, which succeeds the systole of the organ, and the expansion of the iris, in the contraction of the pupil of the eye, are referred by some physiologists to this species of vital motion. During the dilatation of the heart, the organ swells up, and becomes harder, in expanding to receive or suck up, as it were, the next wave of blood from the veins.

The expansion of the iris, which produces the contraction of the pupil, is regarded as the active motion of the iris, because it is produced by the stimulus of light on the eye; whereas the contraction of the iris, by which the pupil is enlarged, is occasioned by the absence or diminished energy of the proper stimulus of the eye, and is always greatest in cases of paralysis or much debility of the organ.

The structure of the iris, however, is a subject of controversy among anatomists. According to Magendie and others, it is unquestionably muscular, and is composed of two sets of fibres, one of which is exterior and radiated, and by its action dilates the pupil; while the other, which is interior or next the pupil, is circular, forming a sphincter, which, by its contraction, diminishes this aperture. If this be admitted, the contraction of the pupil is the effect of muscular action, and cannot be referred to the expansibility of the iris.

It has been conjectured that the act of absorption may be promoted by the exercise of this power in the absorbent vessels; their inhaling radicles thus opening to receive and suck in the fluids which they are destined to absorb. The extent and limits of this force, however, are not accurately defined.

3. The *alterative*, or *chemico-vital* powers of the living system may be comprehended under the expression, *vital affinity*. It is in these powers that the changes, which take place in the composition of the solids and fluids of the living body, originate. They penetrate and pervade all the organs, determine their structure and composition, and the changes to which, in common with the fluids, they are constantly subjected. The numerous transformations which the fluids and solids of the body undergo, as in chymification, chylosis, lymphosis, hæmatosis, the secretions, nutrition, calorification, and fecundation; and the preservation of a certain degree of cohesion or fluidity in the various animal solids and fluids, in spite of the counteracting influence of ordinary chemical agency, must be referred to this power of vital affinity. The formation of the organic elements of the body, also, as fibrin, albumen, gelatin, &c., are the results of the operation of the same power.

The exercise of this power of vital affinity, is confined principally to the fluids, and is manifested in the successive transformations which they undergo, from the state of crude aliment, as it is received into the system, to that of the nutritive fluids in the highest degree of assimilation. It is the most striking characteristic of this force of vital chemistry, to form compounds and aggregates, which could never be produced by chemical affinity. Under the influence of this power, the elements of animal matter are withdrawn from the jurisdiction of chemical laws, and are maintained in their peculiar states of vital combination, in the midst of a variety of destructive forces, which are exerted in vain to subvert them. A new order of affinities seems to be developed in the elements of these combinations, by the influence of this vital force;

affinities, which cannot be satisfied by the common properties of matter, but which mutually saturate one another, and leave the compound in a state of indifference for all others.*

Vital affinity, however, is not confined in its operations to the production of changes and new combinations in the fluids of the system. The solid tissues, also, are subject to its power. The various structures, of which the body is composed, are formed and nourished by the influence of vital affinity. The structure of a living solid is determined by the same laws, as those which fixed its chemical constitution. The various combinations and the different degrees of aggregation and cohesion of the elements which constitute the different tissues, must be determined by the chemico-vital forces, which operated in combining and arranging these elements. The type of the organs, however, by which their shape, size, and relative position in the system are determined, must be referred to some other power which was impressed upon the germ by the act of generation; a power, which has received the name of the *vis formativa*, or force of formation.

As the formation and nutrition of the different organs and tissues of the body are executed under the control of *vital affinity*, and as the different modifications of vital power, with which they are respectively endued, result from their organization or vital composition, it is evident that the power of vital affinity is primitive in relation to the other vital forces, or is, indirectly, the parent of them all. This power which is bestowed upon the germ by the act of generation, is excited to activity by the influence of external causes; and the movements, to which it gives rise, determine the developement of the different structures of the body, their organization, and their chemical composition, and as a necessary consequence, the various modifications of vital power, with which they are respectively endued.

* Diction. de Medicine.

II. The physical properties of the animal tissues are *elasticity*, *extensibility*, *flexibility*, *imbibition*, and *evaporation*.

1. The first of these, or *elasticity*, is possessed in the greatest degree by the cellular tissue and its modifications. It is a force, which tends to restore parts, which have been subjected to mechanical extension, to their former state, as soon as the extending cause ceases to act. The cellular tissue enters so universally into the composition of the organs and tissues, that, with the exception of the bones, they are all endued, though in different degrees, with this property. And the organs and membranes are so disposed in the system, that they are kept in a constant state of extension. Thus the extensor and flexor muscles of the same parts counteract each other's elasticity, so that in a state of inaction they are in a condition of mutual extension. The hollow viscera, and the vessels, are kept in a state of distension by the volume of their contents. If the different soft solids were not maintained in this state by the rigidity of the skeleton, there would be a general shrinking and collapse of the organs, by the exertion of this elastic force. If a muscle be divided, the two parts recede from each other, leaving an interval between the two divided ends. When the hollow organs are evacuated, they contract by their elasticity, until their cavities are obliterated. The cartilages are highly elastic; and this property in the sterno-costal cartilages, is one of the forces by which the movements of expiration are accomplished. The elasticity of the pulmonary tissue, also, contributes to the same effect. The elasticity of the intervertebral cartilages occasions a difference in the length of the vertebral column, and consequently in the height or stature of the body, at different times of day. Hence, a person is usually a little taller in the morning than in the evening. The dilatation of the heart, which alternates with the systole of the organ, is ascribed by some physiologists to the exertion of its elasticity, overcome at first by the muscular contraction of the ventricles, but acting with effect as

soon as the stimulus, which excited the organ to contract, is removed by the expulsion of the blood from its cavities.

The elasticity of the arterial tissues is an essential force in the circulation of the blood. This force constantly reacting upon the column of blood, which is projected into these vessels by the heart, and keeps them distended, maintains the motion of the blood in the arteries, and propels the vital fluid towards the termination of the arterial system. The contractility of the coats of the various canals which carry colorless and secreted fluids, is of a vital character, but is probably assisted by the elasticity of these tunics.

The elasticity of the animal tissues, though regarded as a mere physical property, is partly of a vital character, as appears from several facts. The contractility of the cellular tissue, e. g. is almost wholly destroyed by death. It is also excited to action by certain impressions, especially by heat and cold, in some instances by light,* and by some other stimulating agents. Moreover, it varies at different periods of life, in certain states of disease, and in short, according to a variety of circumstances, which influence the state of nutrition.

2 and 3. *Flexibility and extensibility.*—These physical powers exist in various degrees in different parts. The ligaments of the joints are endued with great flexibility, as the free motions of these parts require. They are, also, possessed of some degree of extensibility.

The tendons possess but little extensibility; and for an obvious reason. As they are attached to muscles, and serve to conduct the moving force exerted by these organs, to the bones, it was evidently necessary, that they should not yield, themselves; otherwise the moving force would be partly expended or absorbed by them, before its arrival at the bones.

4. *Imbibition.*—Another important physical property of the animal tissues, is *imbibition.*

* Tiedemann.

If a liquid be placed in contact with an animal tissue, after a certain time it will be found to have penetrated into the latter, as it would into a sponge. All the soft animal tissues possess this power of imbibition. Some of the tissues absorb with great facility, as the serous membranes and the small vessels; others, as, e. g. the epidermis are penetrated by fluids with much greater difficulty.

The phenomena of imbibition are curious; and they appear to depend both on the nature of the fluid absorbed, andthe texture of the absorbing tissue.

Detrochet found, that on filling the intestine of a chicken with milk, or some other dense fluid, and plunging it into water, the milk passed out of the intestine through its coats, and the water into it, in the opposite direction; and from repeated experiments of a similar kind, he deduced the conclusion that whenever an organized cavity containing a fluid, is immersed in another fluid less dense than the former, there is a tendency in the membrane to expel the denser fluid, and to absorb the rarer. And if the contained fluid be the rarer, then the passage of the two fluids occurs in the opposite directions.

The same phenomena are exhibited by the gases. If a bladder be filled with pure hydrogen gas, and exposed to atmospheric air, the hydrogen in a short time will become contaminated with atmospheric air, which penetrates through the coats of the bladder.

It appears, on the whole, that substances formed of organic matter, imbibe, or are penetrated by, fluids of various kinds, and all kinds of gases; and that every animal and vegetable tissue is possessed of this property.

According to Chevreul, many of the animal tissues are indebted for their physical properties to the water which they imbibe, and retain. If they are deprived of this water, their properties are so much changed, that they are rendered unfit for their proper offices, in the animal economy; but if they are placed in contact with water, and become again impregnated with this fluid, their former properties are restored.

5. *Evaporation.*—This is another physical property, which the animal tissues and organs possess, in common with inorganic bodies. Whenever the body, or any of the organs is placed in circumstances favorable to evaporation, the aqueous part of the fluids begins to pass off in the form of vapor from the exposed surface, and the loss thus occasioned is greater or less, according as the surrounding circumstances are more or less favorable to evaporation. The losses of fluid thus occasioned may be so great under some circumstances, as, in some animals, to cause speedy death.

CHAPTER XII.

The Functions.

By the functions are meant the vital actions. The phenomena of life consist in an assemblage of actions, forming an uninterrupted circle, in which it is impossible to find either beginning or end. Every thing is complicated in the vital functions. Every thing depends on something which precedes it; and the antecedent, in many cases, is equally dependent on that which follows. The circulation of the blood, e. g. is an effect of the motion of the heart, and blood-vessels. Now the motions of these organs, indispensably require the presence of blood circulating in them; that is, the circulation presupposes itself. The heart is enabled to beat and to maintain the circulation, only by means of the blood, which circulates in its own vessels. The heart requires the action of the lungs, and the lungs no less, the action of the heart. Without the action of the lungs, an impure blood would be returned to the left side of the heart, by which its own vessels

would become penetrated, and its power of contraction paralyzed; and without the action of the heart, the functions of the lungs would instantly cease, because no blood would be sent to these organs, either for their own nutrition, or, to be purified by respiration. The lungs are no less under the influence of the brain, and the brain, dependent both upon the heart and the lungs. If the lungs be deprived of the influence of the brain, their functions are instantly suspended; respiration ceases; the dark blood, brought to the lungs by the pulmonary artery, is no longer purified by these organs, but is returned to the heart in the foul state of venous blood, and thence, a portion of it transmitted to the brain, which, like the heart, soon becomes paralyzed by its poisonous influence. The heart, it is true, is not immediately dependent on the brain; but it is so indirectly, through the medium of the lungs. All the functions of the system, the circulation, respiration, innervation, &c., are dependent upon digestion, and digestion indispensably requires the aid of the circulating, respiratory, and nervous systems. It appears, therefore, that all the great functions of life are mutually dependent; that they form a circle, in which it is equally impossible to distinguish a beginning or a termination, and of course to determine which are primitive, and which secondary phenomena.

This mutual dependence and subordination of the functions, renders it impracticable to establish any natural order in treating of them. Begin where we will, there are antecedent phenomena, the knowledge of which is indispensable to that of those we are considering; and, consequently, every classification which can be adopted, must be more or less arbitrary and defective. The arrangement, which will be adopted in this work, as, on the whole, less objectionable than any other, is that of Chaussier.

Chaussier admits four classes of functions; 1, *vital;* 2, *nutritive;* 3, *sensorial;* 4, *genital.*

1. *Vital.*—If we examine with attention the living system in organized beings, we perceive a class of functions, the exercise of which is absolutely

indispensable, every moment, to maintain them in the living state. This first and most important class of functions may properly be termed the *vital functions*, and they are three in number, viz. *innervation*, *circulation*, and *respiration*, or the functions of the nervous system, those of the heart, and those of the lungs. These constitute what has been fancifully called the tripod of life; they are three great columns, which support the whole fabric of the living system.

2. *Nutritive.*—A second class of functions has for its object the introduction into the system of the materials of growth and nutrition, the assimilation of these to the various tissues and organs, and the expulsion from the system of heterogeneous or worn-out elements. This class embraces the four functions, *digestion*, *absorption*, *nutrition*, and *secretion*. The great object of this class of functions is to repair the waste in the organs incessantly caused by the actions of life, and to maintain them in the state of nutrition, necessary to the support of these actions. They may be termed the *nutritive* functions. The exercise of them is not so immediately necessary to life, as that of the first class.

3. *Sensorial.*—The third class may be called the *sensorial functions*, or *functions of relation*. These comprise the sensations, intellectual operations, and the voluntary motions. They establish the relations between living beings and the external world; and become wider in their sphere, in proportion as organized beings ascend in the scale of existence. In the vegetable world, they can hardly be supposed to exist at all. In the inferior animals, they are limited to the narrow circle of mere physical wants; but in the human species, they present their greatest developements. They confer upon man an intellectual and moral existence, and extend his relations to objects and beings, which are elevated far above the sphere of his physical necessities.

These functions, of which the brain is the common centre, are susceptible of great improvement by education, and are much influenced and modified by the power of habit. They are less necessary to life than

either of the two former classes, and their exercise may be suspended for a considerable time without danger.

4. *Genital.*—The fourth class of functions, is the *genital.* These have no concern with the preservation of the individual, but relate solely to the perpetuation of the species. They are distinguished from the others by several peculiarities. In a majority of organized beings, they require the concurrence of two individuals, or at least of two distinct organic apparatuses, one male, the other female. They are not unfolded, until the individual has attained that stage of constitutional developement, termed puberty; and in the human race, and some of the superior animals, they cease in the female, at a certain epoch of life.

CHAPTER XIII.

FIRST CLASS, OR THE VITAL FUNCTIONS.

Innervation.

By the term innervation is meant, the physiological action of the nervous system.

The nervous system is an integral part of the animal organization, the functions of which are in the highest degree important and interesting; but of the precise nature and extent of these, much difference of opinion exists among physiologists.

One great office of the nervous system, about which there is no dispute, is to preside over the sensorial functions, or those of relation; that is, the sensations, and the voluntary motions. But besides this, it exercises an influence over the functions of organic or

vegetative life, the degree and extent of which, however, is not well defined, and is a subject of much controversy among physiologists. It is to this influence of the nervous system, upon organic life in general, that the term *innervation* is, in strictness, applied; while that, which it exercises over the two primary organs of this department, viz. the lungs and the heart, assigns to innervation a place among the vital functions, or those indispensably necessary to life. As presiding over sensation and voluntary motion, the functions of the nervous system fall under the third class, or those of relation.

The nervous system is divided into two great sections, which may be termed the ENCEPHALIC, and the GANGLIONIC; the former of which is sometimes called the nervous system of *animal*, the latter, that of *organic* life.

Encephalic Nervous System.

The *encephalic* nervous system consists of the *encephalon*, and the conductors of sensation and of motion, called *nerves*.

By the *encephalon* is meant the medullary mass contained in the cranium, and its prolongation, the vertebral canal. It is formed of four parts, viz. the *cerebrum*, the *cerebellum*, the *annular protuberance*, and the *spinal marrow*. The *cerebrum*, *cerebellum*, and *pons Varolii*, are termed collectively the *brain*, that globular mass of nervous matter which fills the cavity of the cranium. The greatest length of this organ is about six inches; its transverse and vertical dimensions, about five inches each. Its weight in the adult is between three and four pounds.

1. *Cerebrum.*—The *cerebrum* in man, constitutes much the most considerable part of the encephalon. The upper surface of it, which is convex, is divided longitudinally by a deep fissure into two equal and symmetrical halves, termed hemispheres, which are separated by a fold of the *dura mater*, called the *falx*. The fissure which separates the two hemispheres, is bound-

ed inferiorly by a kind of bridge of medullary matter, called the *corpus callosum*, which reunites the two hemispheres of the brain below.

The whole periphery of the *cerebrum* is intersected by deep fissures, and presents numerous winding eminences, termed convolutions, which exhibit a striking resemblance to a mass of intestines. The fissures between the convolutions are from twelve to fifteen lines deep, and, according to Gall, they result from the packing or folding up of the membrane, of which he supposes the brain to consist. The depth of these fissures is said to bear some ratio to the developement of the intellectual powers.

The inferior surface of the brain is divided into three distinct regions on each side, termed lobes. The anterior and middle lobes are separated by a transverse depression called the *fissura Sylvii*.

In the substance of the brain are found four cavities, termed *ventricles*. Two of these are called *lateral ventricles*, one of which is situated in the central part of each hemisphere. They are irregular in their shape, and each has three winding prolongations, which are termed *cornua*. The anterior cornua are separated by a transparent membranous partition, called the *septum lucidum*, composed of two laminæ, the separation of which leaves a small cavity between them, called the *fossa Sylvii*, or the fifth ventricle. The two lateral ventricles communicate with each other by an opening, called the *foramen of Monro*.

In the lateral ventricles several parts are found, for a particular description of which, we must refer to books on anatomy. Among them are the *fornix*, which is a flat body of a triangular shape, supporting the *septum lucidum*, having its upper surface contiguous to the *corpus callosum*, and its lower resting upon the *choroid plexus*, and the *optic thalami;* the *corpora striata*, which are two smooth eminences, situated in the anterior part of the lateral ventricles, and, on being cut into obliquely, exhibiting a striated appearance, owing to alternate streaks of grayish and whitish matter; the *optic thalami*, two oval eminences, lying

between the diverging extremities of the corpora striata, and their upper surface forming a part of the floor of the ventricles; the *commissura mollis*, a band of cineritious matter, which connects the convex surfaces of the optic thalami; the *tænia semicircularis*, a line of white matter running between the convex surfaces of the optic thalami, and the corpora striata; the *plexus choroides*, situated under the fornix, consisting of a plexus of tortuous vessels, covering the optic thalami, and the corpora striata, and extending into the inferior *cornua* of the lateral ventricles. This plexus returns its blood, by two veins, called the *venæ Galeni*, which run backward and enter the *sinus rectus*. Between the optic thalami and the crura cerebri, is a deep fissure, which communicates with the lateral ventricles by a small aperture at its upper and fore part. This is called the *third ventricle*.

2. The *cerebellum* or little brain, is, next to the latter, the most voluminous part of the encephalon. In the adult its weight is about one-eighth or ninth part of that of the cerebrum. It is situated under the posterior lobes of the cerebrum, from which it is separated by the *tentorium*. Like the brain, it is divided into two lateral halves by the lesser falx, and it is composed of two hemispheres, united behind, by the vermiform processes which rest upon the *medulla oblongata*, and before, by the *pons Varolii*. On its upper surface, it presents five fasciculated lobules, common to both lobes, and disposed in transverse concentric bands. The inferior part of the cerebellum presents a convex surface, on which may be distinguished four lobules disposed in concentric arches. When a section is made between the two hemispheres a beautiful arborescent appearance presents itself, formed by the peculiar arrangement of the white and gray matter of the brain, which is termed *arbor vitæ*. In the cerebellum exists a cavity called the *fourth ventricle*. The sides of this cavity are formed by the *crura cerebelli*, the anterior part by the medulla oblongata, and the upper and back part, by the *valve of Vieussens*. The

third and fourth ventricles communicate with each other by an opening, termed the *aqueduct of Sylvius.*

3. The *annular protuberance*, or *pons Varolii*, is a large round eminence situated between the cerebrum and cerebellum, and apparently formed by the union of processes from them, termed the *crura cerebri*, and *crura cerebelli.* The posterior surface of the pons Varolii presents, on its upper part, four tubercles, termed the *tubercula quadrigemina.* The two superior, which are larger and more prominent than the inferior, are termed the *nates;* the two others, the *testes.* The *pineal gland* corresponds to the point of intersection of the two groves, which separate the tubercles.

4. The *medulla spinalis*, or spinal marrow is a cylindrical cord of nervous matter, which originates from the pons Varolii, passes downwards through the occipital foramen, and extends through the vertebral canal as far as the first vertebra of the loins, where it terminates; forming with the other parts of the encephalon, what is sometimes termed the cerebro-spinal axis. That part of it, which extends from the pons varolii to the occipital hole, is termed the *medulla oblongata.* On its surface, it presents four eminences, termed the *corpora pyramidalia*, and the *corpora olivaria.* The two former are oblong bundles of medullary matter, lying contiguous to each other; and on the outside side of these are the two others, which, from some resemblance in shape to olives, are called corpora olivaria.

The posterior surface of the medulla oblongata is contiguous with the pons Varolii, and contributes to form the fourth ventricle. On each side of the upper and back part of the medulla oblongata, are situated two oblong eminences termed the *corpora restiformia.*

The remaining part of the *medulla spinalis* is a long cylindrical cord, occupying the vertebral canal, and extending from the occipital foramen to about the level of the first lumbar vertebra. On its anterior surface, a deep fissure extends through its whole length, dividing it into two equal lateral parts. Its posterior surface, also, is divided by a median groove.

The spinal cord is considered by some anatomists as consisting of four columns, two ascending to the cerebrum, and two descending from the cerebellum; by others as consisting of two only. According to Bellingeri, it consists, throughout its whole course, of six whitish or medullary strands; viz. two anterior, two lateral, and two posterior. The two anterior are separated from each other by the anterior median furrow, and from the lateral strands by the anterior horns of the gray matter. The posterior strands are separated from each other by the posterior median furrow, and from the lateral strands either by the posterior horns of the gray matter, or by the posterior collateral furrows.

The anterior strands are continuous with the corpora pyramidalia, and the *crura* of the brain, and may be termed the *cerebral* strands of the cord. The lateral columns are continuous with the corpora restiformia, and may be denominated the *restiform* strands. And the posterior columns communicate directly with the cerebellum, and may be termed the *cerebellic* strands.

The vertebral cord, instead of exhibiting the appearance of a regular cylinder, presents two remarkable enlargements, one of which extends from the second cervical nerve to the first dorsal; the second is comprised between the first lumbar and the third sacral nerve. The first of these is larger than the second, and the volume of each of them appears to be in the direct ratio with the developement of the corresponding upper and lower extremities. This relation exists in the fetal state, and continues after birth, and according to Serres, the bulbs of the spinal cord, as well as the limbs which correspond with them, progressively increase until the age of thirty years; and on the approach of old age they begin to diminish, and this diminution is accompanied with an atrophy of the upper and lower extremities.

The substance of the encephalon presents two distinct kinds of matter, one termed the cortical or cineritious, the other, the medullary or white. The first

constitutes the external part of the brain, covering the subjacent matter to the depth of about one-sixth of an inch, and entering deep between the convolutions. It is of a grayish color, and of a firmer consistence than the medullary matter. The cortical substance is essentially vascular, and perhaps is designed to protect the brain from the impulse of the blood, by dividing the vessels sent to it into infinitely small twigs. It also serves, perhaps, to nourish the medullary part.

The medullary or white matter is situated interiorly. It constitutes much the larger portion of the whole mass of the brain, and is traversed by a great number of ramifications of blood-vessels. The mass of the brain seems to be formed of an expansion of the fasciculi of medullary fibres of the medulla oblongata, and especially to originate from the corpora pyramidalia and olivaria. The fibres of the former from each side decussate each other, and contribute to the formation of the opposite part of the brain. Besides this lateral decussation of the brain, there exists according to some physiologists, an antero-posterior one; since the effects of a lesion of the corpora striata are said to be manifested in the legs, and those of an injury of the optic thalami, in the arms.

The brain is subject to several motions. During sleep it is said to become less turgid, and to suffer a degree of collapse; but on waking, it rises again, and fills more completely the cavity of the cranium. The difference depends on the different degrees of activity of the brain, in these two states of the system. Another motion depends on respiration. The brain rises during expiration, but sinks in the act of inspiration. A third depends on the pulsations of the heart, with which it synchronizes. During the systole of the heart, the blood is propelled forcibly into the arteries of the brain, and communicates a pulsatory motion to the organ, which sinks again during the diastole of the heart. The spinal marrow is subject to similar motions.

These motions of the brain are said to be a prerogative of the higher classes of animals, the *mammalia;* for they are not observed either in birds, reptiles, or fishes.

The brain receives its blood by the vertebral arteries and the two internal carotids; the principal branches of which occupy the base of the brain. Numerous veins ramify over the surface of the organ, and terminate in osseo-fibrous canals, which open into the jugular veins. The quantity of blood which it receives, is very great, amounting, it is supposed, to one-eighth of the whole quantity which issues from the heart.

Chemical Analysis of the Brain.

The analysis of the substance of the brain, exhibits the following results:

Water, - - - -	8.000
Albumen, - - -	700
White fatty matter, - -	453
Red do. do. - -	70
Osmazome, - - -	112
Phosphorus, - - -	150
Sulphur, - - - -	515
Traces of phosphates of potash, lime, and magnesia, and muriate of soda.	
	10.000

Envelopes of the Brain and Spinal Marrow.

The encephalon is contained in a large, roundish case, formed of bones, and prolonged inferiorly into a cylindrical canal. The globular case is termed the *cranium*, and its prolongation, the *spine*. The cranium is formed of eight bones, viz. the *frontal*, the *ethmoid*, the *sphenoid*, the *occipital*, the two *parietal*, and the two *temporal* bones; and it contains the cerebrum,

the cerebellum, the pons Varolii, and the medulla oblongata. The spine is a column, composed of twenty-four perforated bones, called vertebræ, piled one upon another, in such a manner as to form a continuous canal, and distinguished into three kinds, according to their position in the column; viz. seven *cervical*, twelve *dorsal*, and five *lumbar*. It is terminated by two other bones, the *os sacrum*, and the *os coccygis*, and it contains the vertebral part of the spinal cord.

Within its bony case, the encephalon is enveloped by three membranes, viz. an external, termed the *dura mater*, a middle, called the *arachnoides*, and an internal, or the *pia mater*.

1. The *dura mater* is the external envelope of the brain. It is a strong fibrous membrane, which forms the internal periosteum of the cranium, adhering loosely to the bones of the skull, except at the sutures and foramina. By maceration it is divisible into two or more laminæ.

Its internal surface forms several folds or duplicatures. One of these constitutes the *falx cerebri*, which separates the two hemispheres of the brain from each other. Its upper edge, extending from the frontal ridge to the middle groove of the occipital bone, contains the superior longitudinal sinus. Its lower edge, which passes over the corpus callosum, contains the inferior longitudinal sinus.

Another process of the dura mater, is the *tentorium cerebelli*, which is a membranous partition, separating the cerebrum from the cerebellum. Its outer circumference contains the lateral *sinuses*.

The *falx cerebelli* is another process of the *dura mater*, which lies between the lobes of the *cerebellum*. These different partitions appear designed to maintain the principal divisions of the encephalon in their respective situations, and to prevent them from being compressed by one another. In animals, whose habits of life lead them to spring down from elevated places, as the cat, there are bony partitions between the principal parts of the encephalon, instead of the membranous folds of the dura mater.

2. The *arachnoides* is situated between the dura mater and pia mater. It is a serous membrane, and consequently forms a closed sac. It is expanded over the convolutions of the brain without dipping into the fissures which separate them, and over the cerebellum, and the base of the pons Varolii. It forms a sheath for all the nerves and all the vessels which pass into, or out of, the cranium. It also passes downwards into the vertebral canal, envelopes the spinal marrow, and gives a sheath to each of the vertebral nerves. This membrane penetrates into the third ventricle by a small opening between the corpus callosum, and the tubercula quadrigemina; it lines the third ventricle, and is continued over the parietes of the lateral and fourth ventricles, into which it penetrates through the *aqueduct of Sylvius*.

3. The *pia mater* is the third membrane of the encephalon. It is a loose cellulo-vascular membrane, which immediately invests the brain, dipping into the fissures which separate the convolutions, and covering the superior surface of the corpus callosum; enveloping, inferiorly the base of the brain, the pons Varolii, and the surface of the cerebellum. It penetrates into the third and lateral ventricles, where it forms the *choroid web*, and the *plexus choroides*. It appears to be a delicate tissue of blood-vessels, connected and supported by soft cellular membrane.

The pia mater, which invests the spinal marrow, is connected to the *arachnoid* membrane by a loose cellular tissue and by blood-vessels; leaving, however, an interval between the two membranes, which is filled by a liquid. This space communicates with the ventricles of the brain by means of the fourth ventricle. The fluid, which thus surrounds the spinal marrow, it is conjectured, may serve the purpose of blunting the shocks or concussions accidentally impressed upon the spine, and thus of preserving the cord from mechanical injury. According to Ollivier, a spinal fluid, also, exists between the two laminæ of the arachnoides itself. Magendie informs us that the spinal fluid exists in all the mammiferous animals as well as

man, and at every period of life, occupying the whole length of the vertebral canal.

The *encephalic* nerves constitute the second part of the encephalic system. These nerves are white cords, extending from the brain or spinal marrow to every part of the system, and are the conductors of sensitive and motive impressions. They are disposed in symmetrical pairs, and are composed of filaments, connected together by cellular tissue.

Of these nerves there are forty-three pairs. Two pairs originate from the cerebrum; viz. the *olfactory*, and the *optic*. Five pairs from the pons Varolii and its peduncles, viz. the *motores oculorum*, or third pair; the *pathetici*, or fourth pair; the *trifacial*, or fifth pair; the *external motory nerves of the eye*, or sixth pair; and the *facial* nerve, or seventh pair.

The remaining thirty-six pairs originate from the spinal marrow; viz. five from the medulla oblongata; viz. the *auditory* nerve, or eighth pair; the *glosso-pharyngeal*, or ninth pair; the *pneumo-gastric*, or tenth pair, sometimes called the eighth pair, and the *par-vagum;* the *hypoglossal;* and the *spinal accessory*. Eight arise from the *cervical* part of the spinal marrow; twelve from the *dorsal;* five from the *lumbar;* and six from the *sacral*.

All these nerves furnish numerous filaments, some of which pass directly to the organs to which they are destined, and which, for the most part, are the senses and the muscles of voluntary motion; others form numerous anastomoses between the encephalic and the ganglionic nervous systems; and a third class are employed in the formation of *plexuses*, which consist of a net-work of filaments proceeding from different branches, interlaced together.

The plexuses formed by the encephalic nerves, are four in number; the *cervical*, *brachial*, *lumbo-abdominal*, and *sacral*.

1. The *cervical* plexus is formed by the anterior branches of the second, third, and fourth cervical nerves, is situated in the lateral part of the neck on a level with the second, third, and fourth vertebræ, and

gives rise to four principal nerves, which are distributed to the head, neck, and the superior parts of the thorax.

2. The *brachial* plexus is formed by the anterior branches of the four last *cervical*, and the first *dorsal* nerves. It lies concealed, in a great measure, in the cavity of the axilla, and gives rise to eight principal branches, distributed to the thorax, shoulder and arm.

3. The *lumbo-abdominal* plexus is formed by the anterior branches of the five lumbar nerves, lies behind the psoas muscle, and gives origin to six principal nerves, the five first of which are distributed to the parietes of the pelvic cavity, and most of the organs contained in it; and the last, termed the lumbo-sacral nerve, descends into the pelvis, and unites with the sciatic or sacral plexus.

4. The *sacral plexus* is formed by the anterior branches of the four first sacral nerves, occupies the sides of the pelvic face of the *sacrum*, and gives off three principal branches, the two first of which are distributed to the cavity of the pelvis, and the viscera contained in it, and the third, an immense nerve termed the *sciatic*, is distributed to the lower limbs.

Ganglionic Nervous System.

The second grand section of the nervous system is called the *ganglionic*, and sometimes the nervous system of organic life.

By *ganglions* are meant small bodies of a grayish white color, of a roundish, or elongated shape, varying in volume from the size of a hemp-seed to that of an almond; most of them extending in a series along the sides of the vertebral column from the base of the cranium to the superior extremity of the coccyx, and connected together by nervous filaments.

Each ganglion transmits nerves both upwards and downwards to the ganglions, nearest it, and others to anastomose with the cerebro-spinal nerves. Some of them furnish branches, which are distributed immediately to certain organs, as to the arterial coats, or

to particular viscera. Thus, the *ophthalmic ganglion* gives origin to the *ciliary* nerves; the *submaxillary*, to the filaments which supply the salivary glands; the *spheno-palatine*, the *cavernous*, and the *naso-palatine*, to branches which are distributed to the arteries and neighboring parts, &c. But most of the filaments proceeding from the ganglia, are destined to the formation of the numerous plexuses belonging to this system. Thus the cervical ganglions supply filaments, which form the three cardiac nerves, superior, middle, and inferior, which terminate in the cardiac plexus. The thoracic ganglions, from the fifth to the eighth or ninth, inclusive, send off filaments, which contribute to the formation of the great splanchnic nerve; and the tenth and eleventh furnish branches, which form the little splanchnic nerve.

The ganglions are numerous, and are found in different situations. Most of them extend in a series along the vertebral column; six are found in the head, and several in the abdomen.

The ganglions, which exist in the head, are the *ophthalmic*, the *spheno-palatine*, the *cavernous*, the *naso-palatine*, the *sub-maxillary*, and the *otic*, or the ganglion of Arnold. Of those, which lie along the vertebral column, three, or sometimes only two, are found in the neck, and are called the *cervical* ganglions; eleven or twelve, in the *dorsal* region; five, four, or sometimes only three, in the *lumbar;* and three in the *sacral.*

In the abdomen, are found the great *semi-lunar* ganglions, situated on each side of the aorta, on a level with the cœliac artery. By their superior extremity, these ganglions receive the great splanchnic nerves, and by their inferior, they communicate with each other. A number of smaller ganglia surround the two semi-lunar, and are connected with them by anastomosing filaments. This collection of ganglia and nervous filaments interlaced together, constitutes the *solar plexus.*

Plexuses formed by the ganglionic nerves.—The nervous branches furnished by the ganglions, unite in

a great number of points with branches of the encephalic nerves, forming inextricable plexuses. From these, originate numerous branches, some of which are distributed to the neighboring organs, but much the larger portion to the coats of the arteries, which they accompany in their principal divisions, forming secondary plexuses.

The principal of these plexuses are the following, viz.:

The *Cardiac* plexus, formed by the three nerves of the same name. From this plexus branches arise, which form the *coronary* plexus:

The *pulmonary* plexus, formed by filaments of the pneumo-gastric nerve, and the anterior branches of the first thoracic ganglions:

The *solar* plexus, formed by the great and little splanchnic nerves, and by numerous branches furnished by the semi-lunar ganglion and its accessories. From this great centre spring branches which serve to form a great number of secondary plexuses, as the *diaphragmatic* plexus; the *cœliac*, from which originate the *coronary* of the stomach, the *hepatic*, and the *splenic;* the *superior* and *inferior mesenteric*, the *renal*, whence is formed the *spermatic*, &c.

The ganglionic system is termed collectively, the great sympathetic nerve. It seems to arise from the sixth cerebral nerve, and from the vidian branch of the fifth. It receives filaments from the seventh, eighth and ninth, and all the spinal nerves, to the lumbar region, and extends to the pelvis, where it terminates.

Functions of the Nervous System.

The functions of the nervous system may be divided intot wo general classes; the first, those of *relation*, comprehending the sensations, voluntary motions, and the intellectual operations; the second, those by which it influences the other functions of the system, as the respiration, circulation, digestion, nutrition, secretion, calorification, &c.

The first class of these functions does not, in strict propriety, fall under consideration at present, because it constitutes the third general class, into which the functions of the system are distributed, viz. the *sensorial*, or those of relation. It is the second class, viz. those by which the nervous system controls, or influences the other functions most necessary to life, particularly respiration, and the circulation, which finds a place among the vital functions; though it is proper to state, that several distinguished physiologists have embraced the opinion, that innervation is the first and most indispensable condition of life; that it constitutes the very essence of vitality; is common to all organized beings, without exception, and is essential to every manifestation of life.

In treating of the functions of the nervous system, we shall consider separately the different parts of which it is composed, viz. the brain, spinal marrow, and nerves.

I. The *brain*, comprehending the *cerebrum*, *cerebellum*, and *pons Varolii*, may be considered as the great centre of this section of the nervous system, and one of the most important organs in the whole animal economy. It is the great developement of the brain in the human race, which raises man so far above all other animals, even those, which from their near approach to man in external shape and internal organization, are termed anthropomorphous. The functions over which the brain presides, are the sensations, the voluntary motions, and the intellectual and moral faculties. It is the seat of consciousness, and of the feeling of individuality, the temple in which is enshrined the perceptive, thinking, and willing principle. The spinal marrow and nerves are subordinate organs, whose office it is to transmit impressions from the organs of sense to the brain, and the cerebral influence in the contrary direction, to the muscles of locomotion and voice. Besides these, which are the sensorial functions of the brain, it exercises an important influence over many of the other functions of the system, particularly *respiration*, and the *circulation*, as has been already

observed. These two classes of the cerebral functions, though differing essentially from each other, I shall not separate, but consider together; while under the third class of the functions, or those of relation, will be considered the senses, and the subject of voluntary motion.

1. *The sensorial functions of the brain.*—These include sensation, voluntary motion, and the intellectual and moral faculties.

Sensation.—The organs of sense and the nerves are the immediate seats of sensation, but its ultimate seat is the brain. Every sensation we experience, from whatever cause it originates, and by whatever channel it is introduced, requires the intervention of the brain, before it can be felt. The impression itself is made upon some organ or sensible part, more or less remote from the brain; but before sensation can be excited by it, the impression must be conveyed to the brain, and in some way or other modified, or digested, as it were, by this organ. Of this the proof is perfectly conclusive. If the nerve, which connects an organ of sense with the brain, be divided or compressed, no sensation will be excited in the mind by impressions made upon the organ. The same physical effect will be produced as before by the external agent; but the channel between the organ of sense and the brain being obstructed, the impression is no longer conveyed to this great focus of sensation, and no feeling, consequently, is excited. A circumstance truly curious in this process of sensation is, that, though the brain is the ultimate and real seat of sensation, yet every sensation is always referred to the organ of sense, on which the impression which gives rise to it, is made; so that there would appear to be a double organic action in all cases of sensation, viz. one from the organ of sense to the brain, by which sensation is excited; the other from the brain, towards the organ, bymeans of which it is referred to the latter.

The agency of the brain in sensation is strikingly illustrated by those curious cases of delusive sensation, which sometimes occur in persons who have lost some

of their limbs, and who complain of pain or some other sensation in a part, which no longer exists. Here the brain is evidently the only seat of the sensation; and this is as real, as if the part to which it is referred, actually existed. For the essence of a substance consists in being felt. When it is felt, it exists; when it is not felt, it does not exist. These sensations are delusive only in being referred by the mind to a part, which has no existence; but this only proves that the reference itself is a cerebral action, and may be exerted even in the absence of the organ, to which the reference is made.

In certain diseases or injuries of the brain, by which the organ is rendered incapable of exerting its usual powers, impressions upon the organs of sense excite no sensation in the mind. The organs of sensation, which are the recipients of the impressions, and the nerves proceeding from them to the brain are uninjured; but no sensation is excited, because the brain is unable to react upon, and to digest the impressions received from them. In such circumstances, as a person receives no sensations from any of his senses, external or internal, he is in a state of general insensibility. A similar torpor of the brain may be produced by the action of opium, alcohol, and other narcotics; and, accordingly, we find that persons completely under the influence of these agents, are in a great measure insensible to external impressions.

There is another state of the system in which the action of the brain is suspended, while this organ, as well as the organs of sense and the nerves retain their integrity, but in which, impressions made upon the senses, excite no sensation in the mind. This state is sleep. In this periodical inaction of the brain, the senses partake, because they derive their power of being excited by external impressions, from their connection with this organ. No impression upon the senses is noticed or excites consciousness, merely because the brain, in a state of repose, is incapable of receiving them, and of reacting upon them. If, however, these impressions, whether made by external

causes, or produced by affections of the organs themselves, are of a certain degree of strength, they may so far excite the action of the brain, as to give rise to an imperfect sort of sensation, or to that shadowy kind of consciousness, which we term dreaming.

On the other hand, the activity of the brain may be so absorbed by its own peculiar functions, as profound meditation, or exclusive attention to some engrossing subject of thought, that impressions upon the senses are not perceived, because the cerebral power is already fully occupied, and none can be spared to give audience to these messages from the senses.

In the cases enumerated above, sensation is not excited, because the brain does not react upon the impressions transmitted from the senses. It might be conjectured from this, that if the action of the brain directed to these impressions, could in any way be increased, the sensations excited by them, would become more vivid than under the ordinary degree of cerebral reaction. Now the fact is found strictly to accord with theory in this case. We have the power of increasing the activity of the brain, by an effort of the will, or by an energetic concentration of the attention upon the impressions received from the senses; and when we exert this power, we find that the increased cerebral energy adds strength and distinctness to the resulting sensations. Slight impressions and such as, perhaps, would scarcely have been perceived under the circumstances, which are constantly distracting and dissipating the cerebral energy, become distinct and even vivid sensations, when the scattered rays of the mind are recalled, concentrated together in a focus, and thrown directly upon them. The action of the brain is, therefore, as essential an element of sensation, as the impressions made upon the organs of sense.

One further proof that the brain is the ultimate organ of sensation, may be noticed in this place. In certain affections of the brain, sensations are sometimes excited by the mere action of the brain itself, without the corresponding impressions upon the senses.

We have examples of this curious fact in certain nervous diseases, as catalepsy, hypochondriasis, and mania. Insane persons sometimes listen attentively to fancied strains of celestial music, to which they earnestly call the attention of others. In the same manner, the tales of visions and apparitions, which have been so frequently told, and so generally discredited by all but the ignorant and the superstitious, admit of an explanation in perfect consistency with physiological principles. The brain has been highly excited by the operation of fear and awe, upon ardent imaginations. The action of the brain has naturally corresponded with the state of feeling which gave rise to it, and has, accordingly, been such, as the actual impression of some fearful object upon the senses, would naturally have produced in the brain; and according to the law which operates in all cases of actual sensation, it has been accompanied by a reference to the appropriate organ of sense. The shape under which the hallucination will be embodied in such cases, will probably be determined by accidental circumstances, and the habitual or prevailing associations of the individual.

It is remarkable, that though the brain is the ultimate seat of sensation, yet both the cerebrum, and cerebellum themselves are destitute of sensibility. Wounds of these parts, as it seems to be established by experiments, do not excite pain. The whole of the hemispheres has been pared away, the cerebellum removed in the same manner, the corpora striata, and the optic thalami cut away, and yet the animal subjected to this shocking experiment, remained perfectly passive, exhibiting no indications by cries or struggles, that it was suffering pain. But as soon as the operator reached the tubercula quadrigemina, trembling and convulsions immediately took place. The medulla oblongata, and spinalis are highly sensible. According to Magendie, sensibility exists in an exquisite degree in the spinal marrow, particularly on its posterior surface; while on the anterior it is much more feeble. Very acute sensibility, also, exists in the

sides of the fourth ventricle; but this property diminishes in approaching the anterior part of the medulla oblongata, and becomes very feeble in the tubercula quadrigemina.

Voluntary motion.—The brain is, also, the organ of the will, the point of departure of all our voluntary motions. The immediate instruments of motion are the muscles. It is by the contraction or shortening of these, that motions are impressed upon the moving parts of animal bodies. The muscles possess a peculiar power of contracting, upon the application of certain stimulants. Thus, mechanical irritation applied to muscular fibres, excites them to contract; and without the application of some stimulant power, the contractility of the muscles remains in a dormant state, and the organ does not contract. Now the stimulus which acts upon the voluntary muscles, so as to excite their faculty of shortening themselves to exert itself, is the influence of the brain, set in motion by an act of the will. No voluntary action can be performed without the agency of the brain. Of the mechanism of these actions we are totally ignorant. We are conscious only of the two extremes of the phenomena, the act of the will, which is an immaterial agent and which by an internal sentiment we refer to the brain, and the physical effect to which it leads, viz. the motion we will to produce; and, notwithstanding the distance which separates the two places where the cause operates, and where the effect is produced, we are not conscious of any interval of time between the two phenomena. The energy of the brain is conveyed, as if by electricity, to the instruments of motion, which are instantly excited to their appropriate actions.

The cerebral influence, however, may be set in motion by other causes besides the will, and contractions of the voluntary muscles be excited not only without the agency of volition, but even in spite of the strongest efforts of this faculty to prevent them. Thus, any irritation, applied to the brain, or developed in it by disease, will frequently excite involuntary contractions of the muscles, which usually act

only under the will. Irritations, also, seated in other parts of the body, as the alimentary canal, may excite the brain sympathetically, and determine the cerebral influence to the muscles of voluntary motion, giving rise to those involuntary contractions, which are called convulsions or spasms. In such cases a person may retain his consciousness, and the power of the will may exist in full vigor; and yet, it is wholly unable to restrain the contractions of the muscles excited by the influence of a more powerful stimulus. The physical stimulus of the brain is more energetic than the immaterial, and the organ acted upon by two opposite forces, yields to that whose action is most powerful.

The proofs that the brain is the seat of the will, the source of voluntary action, are of the same kind and equally conclusive with those, that it is the organ of sensation. If the communication between the brain and any organ of voluntary motion be cut off, by dividing, compressing, or stupifying by opium, the nerve which forms this communication, no act of the will can excite to motion the part so isolated from the brain. In these cases the brain is as capable as ever, of exerting its powers of volition; but the acts of the will can no longer influence the muscle to contract, because the channel of communication between the two organs is no longer open. Certain diseases of the brain, or injuries inflicted upon the organ, abolish the power of volition. It is remarkable that, in these cases, the same cause which destroys the faculty of the will, and of course prevents voluntary contractions of the muscles, may act as a physical or morbid irritation to the brain, and give rise to spasmodic or involuntary contractions of them.

The disease termed paralysis, affords another illustration of the dependence of voluntary motion upon the brain. In this disease, some of the voluntary muscles lose their power of contracting under the influence of the will. The brain still retains its power of exerting an act of the will, but is unable to give effect to the act by exciting the paralyzed muscles to contraction. This condition in hemiplegia, and some

other varieties of palsy, is generally connected with some lesion of the brain, which may be the effect of disease or of accident. It does not so far impair the power of the brain, as to abolish the faculty of volition; but it destroys the physical influence of the acts of this faculty upon the organ, so that the nervous energy is not transmitted to the affected muscles, which consequently are not excited to contraction. It would seem probable from this fact, that the faculty of volition has a distinct seat in the brain, and that its physical influence is exerted upon some other part of the organ, whence it is transmitted to the conductors of the cerebral energy, the nerves. If the seat of the faculty itself be materially injured, no act of the will can be exerted. But if the seat of the injury be any part of the brain, on which the physical influence of the will is exerted, or through which it must be transmitted, in its passage to the muscles of voluntary motion, then though an act of the faculty may be exerted by the individual, yet no corresponding contraction of the voluntary muscles will follow it.

During sleep, in which the brain is in a state of inaction, and the faculty of volition dormant, there is no contraction of the voluntary muscles. A person asleep, if placed on his feet, is unable to support himself in an erect position, but obeys the law of gravitation, and sinks to the ground. If sleep overtakes him while sitting, its first approaches are indicated by nodding of the head forwards; because the strong muscles of the back of the neck are no longer able to support it; and not being poised exactly on its centre of gravity, but resting on the vertebral column behind this centre, its anterior part preponderates.

Intellectual and moral faculties.—The brain is the organ of the intellectual and moral faculties. The proofs of this are of an incontrovertible kind. The connection of the brain with the operations of the intellect, and of the moral faculty, is shown by numerous facts. An internal sentiment leads us irresistibly to refer the acts of the mind and of the moral faculty, to the brain or head. No one ever imagined that

he carried on his reasoning operations in his lungs, stomach, or liver. These organs, like all others, have certain functions peculiar to themselves. The same is true of the brain. A healthy state of certain parts of this organ is necessary to the exercise of the rational and moral powers; and accordingly we find that injuries of the head, frequently destroy or impair the faculties of the mind. The same consequences result from certain diseases of the brain, a fact which is remarkably exemplified in apoplexy, and in insanity—two diseases which, are, probably in all cases, connected with some physical change in the state of the brain. In general, in all cases of *acute* disease, in which the patient preserves his mental faculties unclouded to the last, we may be pretty certain that the brain is unaffected; and, on the other hand, whenever we find him become drowsy, stupid, or insensible, we may be equally sure, that this organ has suffered some physical change, which, in most cases, will be apparent on dissection. Opium, alcohol, and other narcotics, which exert so striking an influence upon the mental faculties, owe this property to their power of producing certain changes in the brain.

Like all the other organs of the body, the brain experiences the effects of the exercise of its functions, in an increase of its volume. If the intellectual powers are duly cultivated, the organ acquires its full developement and growth; if they are neglected, it probably never attains the expansion of which it is capable. This circumstance is important; for it explains the fact, that the neglect of early intellectual culture, in many cases, can never be compensated by subsequent education. The brain, in these cases, has not been sufficiently developed in its organization and volume, by necessary exercise. It is incapable of acting with the energy of a fully developed brain, and no voluntary efforts of the individual can overcome the obstacle; for it is a physical one, connected with the state of the organization. On the other hand, severe exercise imposed upon the brain in its tender state, in young children, is still more pernicious; for it

prematurely exhausts the energy of the organ, and brings on its early decrepitude. The brain at first, under the influence of artificial excitements, is rapidly unfolded, the intellectual faculties soon bud and blossom, every thing gives hopes of an early and abundant harvest, but the fruit never ripens, but falls half-formed to the ground.

Numerous experimental researches have been made in order to determine the functions which respectively belong to different parts of the brain; but, as yet, without very satisfactory results.

The *cerebral lobes* are supposed to be the seats of the faculties of thinking, memory, and the will; and, according to some physiologists, ultimately, of all the sensations.

Vertical pressure upon the hemispheres of the brain, occasions stupor,—an effect, however, which Mayo ascribes to the compression of the medulla oblongata. Lateral pressure is said to be followed by no sensible effect.

The lobes of the brain appear to be that portion of the organ, in which all the sensations assume a distinct shape, and leave durable traces in the memory; a property, by which they furnish the materials of knowledge and judgment. The ablation of one of the cerebral lobes, or a profound lesion of it, is followed by blindness of the *opposite* eye, and by a paralytic weakness of the muscles of the *opposite* side of the body.

If both lobes are removed, much injured or compressed, according to Flourens, there is from that moment neither sight, hearing, smell, taste, memory, thought, nor will. The animal subjected to the operation, sinks into an apoplectic stupor; a fact, from which Flourens infers, that the cerebral lobes constitute the organ of the memory, of the will, and, ultimately, of all the sensations. It is a curious fact, that although the sight of the opposite eye is destroyed when one of the cerebral lobes is removed, the contractility of the iris remains unimpaired. If the conjunctiva, the optic nerve, or the tubercula quadrigemina,

be irritated, the iris contracts with convulsive force; a fact, from which it appears, that while the principle of vision resides in the cerebral lobes, that of the contractility of the iris exists elsewhere.

Magendie, on the contrary, asserts that neither the cerebrum, nor the cerebellum, is the principal seat of sensibility, or of the special senses. He affirms that if the lobes of the cerebrum, and those of the cerebellum, be removed in one of the mammalia, the animal still remains sensible to strong odors, to sounds, and to tastes. He admits that vision is abolished by the ablation of the cerebral lobes; but this fact he accounts for by observing, that vision does not consist in the simple perception of light; but that the action of the apparatus of vision, is almost always connected with an intellectual or instinctive operation, by which we form ideas of the distance, size, shape, and motion of objects; and this intellectual element of vision, he supposes, requires the intervention of the cerebral hemispheres.

On this subject Magendie remarks, that the sense of vision has a threefold seat in the brain; viz. the cerebral lobes in the sense just explained, the optic thalami, and the fifth pair of nerves. An injury of one of the thalami, is followed by a loss of sight in the *opposite* eye, and a section of the fifth pair occasions blindness of the eye on the *same side*. Hence it appears that the influence of the hemispheres, and of the optic thalami upon vision is transverse or exerted upon the opposite sides, while that of the fifth pair is direct.

Admitting, however, that the cerebral lobes are the seats of memory, of the will, and of the sense of vision, it is certain that these faculties may continue unimpaired, when the lobes of the brain are mutilated or wounded. Even deep wounds of the brain are not invariably followed by debility of sensation or motion, or of the mental faculties; facts, which render it probable, that a portion of these lobes, perhaps the central part, may suffice for the exercise of these functions.

The office of the *cerebellum* is supposed to be, to regulate and combine different motions to a determin-

ate object. A wound of one side of the cerebellum is followed by a weakness of the same side of the animal. If the wound be deep, the body on the injured side becomes paralytic. In the experiments of Flourens, however, wounds and injuries of the cerebellum were found to cause a discord, or want of harmony, rather than a weakness, of the voluntary motions. The ablation of it occasioned a loss of power of combining the motions, necessary to the mode of progression which is proper to the species of the animal, subjected to the experiment. The animal appears to be intoxicated, and exhibits a singular propensity to go backwards. Another remarkable phenomenon is a kind of rotation or whirling round, which is said to be sometimes exhibited by persons, after wounds, or in diseases, of the cerebellum. Sometimes patients affected with disease of this organ, whirl round in their beds in a very extraordinary manner. Further, if a vertical incision be made into one side of the cerebellum, the animal rolls over and over, always turning itself towards the injured side; at the same time a want of harmony is observed in the direction of the eyes, one of them being turned upwards and backwards, the other, downwards and forwards. On making a similar incision in the opposite hemisphere parallel to the first, the motion of the animal ceases, and the harmony of direction in the two eyes is immediately restored.

Magendie observed that the same effect was produced by dividing the *crus cerebelli* in a rabbit, as by dividing the cerebellum unequally. The animal survived the experiment eight days; and during the whole time it continued to revolve upon its long axis, except when arrested by some obstacle. The division of the opposite *crus* put a stop to the motion.

If a section of the cerebellum on one side, gave rise to a constant revolution towards the same side, the division of the opposite *crus cerebelli* did not restore the equilibrium, but the animal began to revolve towards the side of the divided *crus*.

These curious phenomena Mayo ascribes to a sensation like vertigo, produced by the lesions of the cerebellum.

Upon comparing the cerebrum and cerebellum together in relation to the effect of injuries upon them, it appears that lesions of the cerebellum give rise to a want of harmony in the voluntary motions; those of the cerebrum, implicate the senses, understanding, and will. Compression of the brain produces the effect of opium; alterations of the cerebellum, the effects of the abuse of alcohol. In the former case there are symptoms of narcotism; in the latter, those of intoxication. Lesions of the cerebrum produce paralysis or immobility; those of the cerebellum, agitation and disordered motions, and especially a disposition to go backwards, and a rotation of the body. Diseases of the cerebrum destroy the harmony of ideas; those of the cerebellum, the harmony of motions. The cerebellum influences chiefly the lower limbs; the cerebrum, the upper.*

The *tubercula quadrigemina* have been supposed chiefly to influence the voluntary motions of the body, the sense of vision, and the contraction of the iris. The removal of one of these bodies, weakens the sight, and the motions of the iris of the *opposite* eye, causing dilatation of the pupil. The total destruction of the tubercles, produces blindness, immobility of the iris, and dilatation of the pupils. Irritation applied to the tubercles, occasions convulsions and contractions of the iris. Magendie, however, remarks, that he had never seen that an injury of the optic tubercle affected the vision in the mammiferous animals, though this effect was very evident in birds.

The destruction of the *pons Varolii*, occasions immobility of the body, and the loss of all the senses. The respiration and circulation are not affected, unless the injury extends to the medulla oblongata. According to Bourdon, the pons Varolii is situated between the functions of the will and those of instinct,

* Bourdon.

exactly on the limits of intelligence and life. Above it, all is voluntary; below it, all is spontaneous and automatic.

The *optic thalami* are believed by some physiologists, to influence the motions of the arms, and the *corpora striata*, those of the lower extremities; so that lesions of the former, it is supposed, may occasion paralysis of the arms, and those of the latter, paraplegia or palsy of the lower extremities.

Paralyses of the arms are said to be more obstinate than those of the legs, because the lesions of the optic thalami are generally the profounder and more durable. Further, as the thalami are nearer the medulla oblongata, morbid affections of them, more frequently affect respiration. Hence paralysis or convulsions of the arms, are oftener accompanied with oppressed respiration than those of the legs.

According to Bourdon, paraplegia is often accompanied with, or preceded by, a pain in the temples; a fact, which is explained by the anterior situation of the corpora striata.

The *optic thalami*, also, like the *tubercula quadrigemina*, are subservient to the sense of vision, and the *corpora striata* to that of smell. So that the same parts of the brain which are instrumental in vision, are subservient to the sense of touch, in regulating the motions of the arm; and the organs of locomotion are allied to the sense of smell by means of the corpora striata, which are subservient to both.

The parts of the encephalon, which seem to be particularly destined to motion, are the corpora striata, the optic thalami in their inferior part, the crura cerebri, the pons Varolii, the peduncles of the cerebellum, the lateral parts of the medulla oblongata, and the anterior part of the spinal marrow.

It may be proper here to mention the opinions of a celebrated Italian physiologist, Bellingeri, respecting some of the functions of the different parts of the brain. Bellingeri endeavors to prove that the cerebral lobes, the anterior strands of the spinal cord, and the anterior roots of the spinal nerves, are subservient to motion;

and that the cerebellum, the posterior strands of the spinal cord, and the posterior roots of the spinal nerves, also, preside over motions. In proof of the first proposition, he refers to numerous authorities, to show that, while injuries and diseases of the superior part of the brain affect chiefly the intellectual faculties, lesions of the middle lobes and corpora striata affect principally the motions of the abdominal or sacral extremities; and that injuries and diseases of the optic chambers, and posterior lobes of the brain, affect chiefly the motions of the thoracic extremities. He, also, adduces experimental proof of the subservience of the anterior strands of the spinal cord, and the anterior roots of the spinal nerves, to the motions of the limbs. In proof of the subservience of the cerebellum, &c. to motion, he adduces the experiments of various physiologists, which show that sections of the cerebellum produce paralysis of the muscles of the *opposite* side. He, also, refers to numerous cases, in which morbid states of the cerebellum gave rise to tetanic rigidity of the muscles, trismus, rigid tension of the extremities, general convulsive motions, and priapism; and others, in which palsy of various muscles was produced by diseases of the cerebellum.

Bellingeri, further, endeavors to prove that the lobes of the brain are subservient to the motions of *flexion;* and the cerebellum, to those of *extension.*

In proof of the first position, he adduces various experiments of different physiologists, as Magendie, Flourens, &c. Thus, Serres found that the removal or injury of one of the *anterior* lobes of the brain, was followed by *flexion* of the opposite *abdominal* extremity; and the removal of both anterior lobes produced the flexion of both abdominal extremities. On the contrary, the division or removal of the *posterior* lobes of the brain is followed by *flexion* of the *thoracic* extremities. The removal or destruction of the hemispheres of the brain causes an irresistible motion of progression forwards; while wounds or destruction of the cerebellum produce a retrogressive motion.— From pathological investigations, Bellingeri infers that

inflammation or any irritation of the cerebral lobes produces spasm, which assumes the form of flexion, and sometimes, also, of adduction of the extremities; from which he infers that the cerebral lobes preside over the motions of flexion and adduction of the extremities. In proof of the proposition that the *cerebellum* presides over the motions of *extension*, he adduces various experiments from different physiologists; the general result of which is, that irritations excited in the cerebellum induce *opisthotonos*, or spasmodic extension of the head, trunk, and posterior extremities; that in some instances of lesions inflicted on the cerebellum, these spasmodic motions may be so violent as to throw the animal completely backwards; and, that the motion of retrogression observed by Magendie in injuries or irritations of the cerebellum, is owing to the spasmodic action thus induced in the extensor muscles, by which the animals are compelled involuntarily to move backwards. In support of the same position, Bellingeri adduces a variety of pathological facts.*

2. *Influence of the brain over the organic functions.* —The influence of the brain over the organic functions is comparatively inconsiderable, being far inferior to that of the spinal marrow. Most of the great functions of the system, however, appear to be more or less influenced by cerebral innervation; as respiration, the circulation, digestion, secretion, nutrition, calorification, &c.

Thus *respiration* is, in some degree, subject to the influence of the brain, because the external muscles of respiration belong to the class of the voluntary muscles, which derive their nervous influence directly or indirectly from the brain. The internal sentiment of the want of respiration, which produces the cerebral reaction upon the external muscles of respiration, must be referred to the seat of consciousness in the encephalon, wherever this may be. This internal sentiment, however, is by no means necessary to

* Edinb. Med. and Surg. Journ. No. cxx.

respiration; for, this function goes on without intermission, when consciousness is suspended, as, e. g. during sleep, and in certain cerebral diseases. And where the latter are accompanied with stertorous or embarrassed respiration, the effect is to be ascribed to compression or lesion of the medulla oblongata. The action of the brain, therefore, is not necessary to respiration; and accordingly we find that the removal of the whole organ does not destroy this function, provided that the medulla oblongata be left uninjured. Acephalous infants have lived some days after birth. In an account of an acephalous child by Mr. Lawrence, it is stated that the brain and the cranium were deficient, and the basis of the latter was covered by the common integuments, except over the foramen magnum, where there existed a soft tumor about the size of the end of the thumb. This child lived four days, and *breathed naturally*, and was not observed to be deficient in warmth until its powers declined. The medulla spinalis was found to extend about an inch above the foramen magnum, swelling out into a small bulb, which formed the soft tumor upon the basis of the skull. All the nerves, from the fifth to the ninth, were connected with this. The most extensive organic disease may exist in different parts of the brain without affecting respiration. Yet, that this function is influenced by the brain, appears from the fact, that certain emotions of the mind produce an evident effect on the movements of respiration.

The *action of the heart*, also, is considerably influenced by the brain. It is well known that violent emotions, and all strong moral affections powerfully influence the action of the heart. A sudden emotion of surprise frequently occasions palpitation. A vivid sensation of joy has, in many instances, occasioned sudden death, by paralyzing the heart. It is related of the painter Francia, that he was struck with such admiration by a painting of Raphael, that he swooned and expired on the spot. The passion of fear, also, produces a strong depressing effect upon the circulation. Terror has, in some instances, caused a mortal

syncope; and aneurisms of the heart have been often produced by this cause. According to Desault, the reign of terror in France, in the year 1793, was uncommonly fruitful in this disease.

Another fact which tends to the same conclusion is, that concussion of the brain is attended with great depression of the action of the heart, and of the capillary circulation, together with coldness of the surface.

Digestion, also, is influenced in some degree by the brain, as appears by the effects upon the function, produced by certain mental emotions. The effect produced by the division of the pneumo-gastric nerves upon digestion, is to be ascribed to the interception, not of the influence of the brain, but of that of the medulla oblongata.

With respect to the other organic functions, which for the most part, are exercised in the parenchyma of the organs, and the capillary vessels, and which derive their powers principally from the ganglionic system, the influence of the brain may be inferred from the disturbance occasioned in these functions by moral causes, such as violent passions, or emotions. These causes take their rise in the brain, and the effects which they produce in modifying the organic functions, are illustrative of the influence of cerebral innervation over the department of vegetative life. The passions affect the capillary circulation and calorification; for, the skin becomes red or pale, and hot or cold, under the influence of certain passions.

The *secretions*, also, manifest the influence of cerebral innervation. Grief increases the secretion of tears; fear, that of the kidneys. A cold sweat sometimes starts out from the skin under the influence of the same moral cause. The peculiar state of the nervous system which exists in hysterical affections, frequently occasions a copious secretion of pale urine, but sometimes produces the opposite effect, and suppresses the secretion. A fit of anger has been known to change the qualities of the milk, so as to give rise to colic, and diarrhea in infants nourished by it. Boerhaave relates a case of this kind, in which epilepsy was excited by

this cause, and continued to return during the whole life of the patient.

The cerebral influence, also, affects *absorption*, and probably *nutrition* likewise. It is well known, that persons under the influence of fear are peculiarly liable to be attacked by contagious, or epidemic disease; while those who are calm and fearless in the general panic, are much less liable to suffer. This fact renders it probable that the passion of fear promotes absorption, as some other debilitating causes undoubtedly do; and that the morbific principle, whatever it be, is thus more easily introduced into the system of persons affected by it. The paralysis of a limb often tends to atrophy or withering; a fact, which appears to evince the influence of encephalic innervation upon nutrition.

These facts, and numerous others of a similar kind, appear to leave no doubt, that the parenchyma of the organs, as well as the capillary system, are supplied with nerves, which subject them, in some degree, to the influence of the brain.

The brain is also believed by many physiologists, to be the instrument of that mysterious vital relation, which exists between, and connects together, the different organs; in other words, it is supposed to be the principal agent of the sympathies.

On the whole, the brain is the organ of intelligence; it directs the means by which we react upon the external world; it exercises an important influence over the functions of internal life; and, as the great centre of the nervous system, is probably the principal organ of sympathy.

These functions of the brain, especially the two latter, render this organ indispensable to life in the higher classes of animals; and according we find that injuries of this organ from accident or disease, are generally, though not invariably, fatal.

Though it be true, however, that the functions of internal life are more or less influenced by cerebral innervation, yet it must not be inferred, that they are dependent on this organ; since it is well known

that full grown fetuses have been born, destitute of every trace of a brain, and even of a spinal marrow. From this, it should seem, that during fetal life the innervation of the ganglionic system is sufficient to maintain the nutritive and vital functions, in their imperfect and rudimentary state; but that after birth, when the individual commences a new and more elevated existence, when all the phenomena of animal or external life start at once into existence, and the brain, their common centre, is roused to the exertion of all its sleeping energies; when two of the most important of the organic functions which are immediately dependent on encephalic innervation, viz. digestion and respiration, first begin their exercise; the empire of the brain is extended over all the functions of life, connecting them together in a bond of reciprocal dependence and sympathy; and cerebral innervation then becomes indispensable to their regular exercise, and consequently to animal life.

Functions of the Spinal Cord.

The influence which this part of the nervous system exercises upon some of the most important functions, places it in the first rank of organs, most necessary to life. The spinal marrow is found in all the higher classes of animals, under different forms, and the more highly developed, in proportion as their whole organization is more perfect. By its direct communication with the brain on the one hand, and on the other with the different parts of the body, it becomes the principal channel of communication between the common centre of sensation and voluntary motion, and the immediate instruments of these functions, viz. all the sensible parts of the trunk and limbs, and the muscles of voluntary motion. It exercises, also, an important influence over many of the organic functions, particularly respiration, calorification, cutaneous transpiration, the digestive functions, and the motions of the heart.

In treating of the functions of the spinal cord, I shall consider first, its sensorial functions; secondly,

those by which it influences the vital and organic ones.

I. *Sensorial functions.*—According to Mayo, it appears from Magendie's experiment of removing the cerebrum, optic tubercles, and cerebellum in a living animal, that the brain may be taken away by successive portions, and yet the animal survive, and exhibit sensation and instinct. But if the mutilation be carried a line further, so as to comprise that small segment of the medulla oblongata, in which the fifth, and eighth nerves originate, consciousness is at once instantly extinguished. From this experiment it would seem to follow, that this portion of the medulla oblongata, instead of the cerebral lobes, is the seat of consciousness. Mayo remarks, further, that the rest of the nervous system derives its vitality, or rather its participation in the phenomena of consciousness, from its continuity with this small portion of the medulla oblongata. In proof of which, he states that in cold-blooded animals, as the frog or turtle, consciousness will continue some time after the head has been severed from the body; and it will remain either in the head or the body, according as the section of the medulla oblongata has been made *below* or *above* the spot just described. If the section be made below this vital part, the body is deprived of sensibility while the head continues to exhibit marks of consciousness. But if the section be made just above the origin of the fifth and eighth nerves, the result is directly opposite; for the head is deprived of life, while the body remains alive. According to Mayo, the stupor occasioned by vertical pressure upon the hemispheres of the brain, is owing to the compression of the medulla oblongata. The same author observes in connection with this subject, that when vomiting has been excited by an emetic, it is arrested by pressure applied to the medulla oblongata.

The spinal marrow may be regarded as a common centre of the nerves, distributed to the muscles of voluntary motion, and of those subservient to general sensibility. It is not, however, independent of the

brain. It is only a conductor, and perhaps we may say a prime conductor, of sensific impressions from the limbs and trunk of the body to the brain in one direction; and of motive impulses from the seat and source of volition, the cerebral lobes, to the muscles of voluntary motion in the other.

It has been known from the infancy of medicine, that injuries of the spinal marrow, occasion a paralysis both of sensation and motion, of the parts, situated below the injured portion of the cord. A division of the cord in any part of its course, always paralyzes the limbs, and that portion of the trunk of the body, situated *below* the seat of the injury, leaving the parts *above*, wholly unaffected. If the injury occur high up in the neck, it causes almost instant death. The involuntary discharge of urine and fecal matter, which is frequently the consequence of injuries of the spine, was referred by Galen to a paralysis of the nervous filaments, which are distributed upon the sphincters of the bladder and rectum. It is also well known, that irritations applied to the spinal marrow, excite convulsions of the trunk and limbs below the seat of the irritation.

The researches of Bell, Magendie and others, appear also to have established the fact, that the anterior part of the spinal cord presides over voluntary motion; and the posterior over sensation. The spinal nerves originate by double roots, one anterior, the other posterior; and Magendie found that dividing the posterior roots of the spinal nerves, which supplied one of the hind legs, completely destroyed the sensibility of the limb, without affecting its power of motion; and, on the other hand, that the section of the anterior roots abolished the muscular power, without impairing the sensibility of the limb. A striking evidence of the same fact is furnished by the *nux vomica*, a poison, which, in some animals, excites the most violent spasms, but which produces no such effect, if the anterior roots of the spinal nerves be previously divided.

It appears, however, that the isolation of these two properties in the anterior and posterior roots of the spinal nerves, is not complete. If an irritation be applied to the posterior roots, contractions are produced in the muscles, to which the nerves are distributed, though they are much less violent than when the anterior roots are irritated. In like manner, slight indications of sensibility are observed, when an irritation is applied exclusively to the anterior roots.

The isolation of these two properties, sensibility and motility, from each other, in the double roots of the spinal nerves, will enable us to account for those cases of paralysis, in which the loss of power is confined exclusively to the sensibility or the motility of the paralyzed part.

The gray central part of the spinal cord, appears to be the principal seat of these two properties; for the roots of the spinal nerves, are found to penetrate into this central portion of the cord.

There is still, however, much difference of opinion respecting the functions of these parts of the spinal marrow. According to Bellingeri, the posterior strands preside over the movements of extension, and the anterior over those of flexion; whence there results an antagonism between these two parts of the spinal cord. The posterior strands produce a relaxation of the sphincter of the bladder, and the contraction of that of the rectum; the anterior on the contrary, preside over the contraction of the sphincter of the bladder, and the relaxation of that of the rectum. The anterior and posterior strands exert no influence upon sensibility, but only on motion. The white matter of the spinal cord is the exclusive seat of motility; while the influence of the gray matter, is confined to the sense of touch.

Experiments, also, seem to have ascertained, not only that the spinal cord is the source of sensation and motion of the trunk and limbs generally, but that the sensibility and powers of motion of any part of the trunk and limbs, depends on that portion of the spinal marrow from which it receives its nerves. If

an animal is made to take strychnine, and the spinal marrow be laid bare, the convulsions in any part occasioned by the poison, are arrested by compressing that part of the spinal cord which corresponds with it; while compression of the brain, or of the medulla oblongata, neither suspends nor checks them in the slightest degree. This fact appears to prove, that the spinal marrow is not *merely* a channel of communication between the brain and the organs of motion, but that the principle of motion resides in this part itself. Experiments, also, make it probable, that the different portions of the spinal cord are capable of acting independently of one another; a fact, which confirms the opinion that the spinal marrow has a power of its own, independent of the brain. Mayo remarks, that the spinal cord consists of an assemblage of independent segments; that each segment, from which a pair of nerves arises, has in itself a mechanism of sensitive and instinctive action, similar to that of analogous parts in the invertebrated animals. In proof of this he adduces the following experiments. If the spinal cord be divided in the middle of the neck, and again in the middle of the back in a body, a few seconds after it has been deprived of life, upon irritating a sentient organ connected with either isolated segment, muscular action is produced. If, e. g. the sole of the foot is pricked, the foot is suddenly retracted in the same manner as it would have been during life. In this experiment a sentient organ is irritated, and the irritation is propagated through the sentient nerve to the isolated segment of the spinal cord, and gives rise to some change, followed by a motific impulse along the voluntary nerves to the muscles of the part.

Still, the peculiar energy of the spinal marrow, is subordinate to the influence of the brain, which perceives and appreciates the impressions, conveyed to it from the sense of touch through the spinal cord, and which reacts in such a manner, that its influence is transmitted through the same channel to the locomotive organs. Without the action of the cerebral lobes, no *voluntary* motion could be originated, and probably no sensation be distinctly and consciously felt.

Influence of the Spinal Marrow over the Organic Functions.

The spinal cord, also, exercises an important influence upon some of the organic functions most necessary to life. The superior part of the spinal cord, or the medulla oblongata, may be regarded as a kind of focus of vitality in the superior classes of animals. In this limited portion of the cerebro-spinal system are concentrated all the nervous forces immediately necessary to life; particularly the nerves which give energy to the lungs, the larynx, the heart, and the stomach, and those which supply the external muscles of respiration; and any cause, which should at the same time suspend the action of all these nerves, would immediately annihilate life.* Hence, the instant death occasioned by an injury of this part of the spinal cord. According to Bellingeri, the lateral strands of the medulla, which are continuous with the *corpora restiformia*, preside over the organic and instinctive functions.

Respiration, especially, is under the influence of the superior part of the medulla spinalis; and lesions of this part of the cord, are always accompanied by symptoms, which point out the dependence of respiration upon it. Lesions of the medulla oblongata instantly annihilate respiration. Injuries of the spinal cord opposite to the second vertebra, also, occasion instantaneous death; because all the respiratory nerves are then injured simultaneously, so that respiration is instantly destroyed by a paralysis of the external and internal muscles of the chest, and those of the neck and nostrils, and by the inaction of the aërial passages and lungs. If the spinal marrow be wounded opposite to the fifth cervical vertebra, or a little higher, respiration becomes laborious, and the motions of respiration are executed only by the muscles of the neck and shoulders, the diaphragm

* Ollivier.

becoming nearly motionless, and the intercostal muscles, paralyzed; and death soon follows from asphyxia. If a lesion be inflicted upon the dorsal portion of the spinal cord, it is followed by immobility of the ribs, because the intercostal muscles derive their nervous influence from this part of the cord. Respiration, however, is still carried on imperfectly by the action of the diaphragm, and the other respiratory muscles, accompanied by the elevation of the shoulders, expanding of the nostrils, opening of the mouth, &c.

It may be asked why a simple section of the spinal marrow at the occiput, produces death, when no other injury is inflicted upon the medulla spinalis, than the mere separation of its vertebral from its cerebral portion. Brachet answers this question by observing that the pneumo-gastric nerves, which originate in the medulla oblongata, receive in the lungs the impression of the want of respiration, and transmit it to the medulla oblongata. In the normal state, the medulla oblongata reacts upon those parts of the spinal cord which give rise to the respiratory nerves of the chest. But, if the communication between the medulla oblongata and the vertebral parts of the cord, be intercepted, the former can no longer transmit its influence to the latter, which, consequently, do not excite the respiratory muscles to action.

The effect upon respiration, of dividing the pneumogastric nerves, is another illustration of the influence of the medulla oblongata on this function. The division of these nerves in the neck, produces a paralysis of the lungs, which soon terminates in asphyxia and death. It also occasions a paralysis of the muscles which dilate the larynx, in consequence of which the aperture of the larynx becomes closed, and opposes an insurmountable obstacle to the introduction of air into the lungs. It is supposed, also, to prevent the transmission of the sentiment of the want of respiration, to the medulla oblongata, and consequently the reaction of this upon that part of the spinal cord which furnishes the respiratory muscles of the chest with nerves.

The influence of the spinal marrow upon the *circulation* of the blood, is by no means so great, as upon respiration. Even the total destruction of the cord does not occasion an immediate suspension of this function. Experiments, however, have ascertained, that the circulation of the blood is considerably influenced by the spinal column. The destruction of the spinal marrow, or of any considerable portion of it, has been found to enfeeble the action of the heart. If the lumbar part of it be destroyed, the circulation is enfeebled in the posterior extremities, but is not affected in other parts of the body, which derive their nervous influence from that part of the cord, which is situated above the injury. And, in general, when any portion of the spinal cord is destroyed, the circulation becomes more feeble in the parts situated below the injured portion of the spine, than in those above. On the whole, it is ascertained that the action of the heart is independent of spinal innervation, but is much *influenced* by it. The heart may act without the spinal cord, but yet is subjected in some degree to this nervous centre.

But the *capillary circulation* appears to be immediately dependent upon the innervation of the spinal cord. The destruction of any part of this nervous centre, always produces a suspension of the circulation of the capillary vessels of the parts which receive their nerves from the destroyed portion. Hence in paraplegia from an injury of the spine, the capillary circulation is sometimes almost wholly suspended; the skin is purple or mottled, from a stasis of venous blood in the small vessels; there is a total absence of cutaneous transpiration; the skin is dry, and there is a constant exfoliation of the cuticle. There is, also, a sensible diminution in the temperature of the paralyzed parts. The developement of caloric in the system, seems to take place in the two capillary systems, the pulmonary and the general; and both these systems derive their nervous influence in a great measure from the spinal cord. Hence, in chronic affections of this organ, attended with a loss of sensation and motion,

there is a sensible diminution of temperature, of which the patient complains. Calorification, however, is not under the exclusive control of spinal innervation. The whole nervous system is probably concerned in it.

That the spinal cord exerts an influence upon *digestion*, is ascertained by pathological facts, and by experiments on living animals. Thus, it has been observed, that the digestive functions are performed slowly and imperfectly in individuals affected with chronic diseases of the spine. According to Bourdon, lesions of the dorsal portion of the cord, are almost always accompanied or followed by colics, indigestion, obstinate affections of the kidneys, spleen, liver, ovaria, &c. Obstinate constipation, followed by involuntary evacuations, is a common symptom of affections of the spinal cord. The section of the cord between the fifth and sixth dorsal vertebræ in a dog, was found to destroy the power of evacuating the bowels, an effect which was undoubtedly owing, in part, to a paralysis of the abdominal muscles, but which was partly to be ascribed to a loss of power in the muscular coat of the intestines, produced by the section of the cord.*

The influence of the medulla oblongata upon digestion, is illustrated by the effect upon chymification, produced by the division of the pneumo-gastric nerves. This operation in living animals, has been found to produce a paralysis of the stomach, by which the muscular contractions of the organ are annihilated, and chymification brought to a stand. It appears, therefore, that the contractions of the muscular coat of the stomach, as well as those of the fibrous tissue of the bronchial tubes, depend on the influence of the medulla oblongata transmitted by the pneumo-gastric nerves.

The functions of *the kidneys*, also, are subject to the influence of the spinal marrow. In certain cases of injury or disease of the latter, the secretion of urine is totally suspended, and in others, it is more or less changed. The division of the spinal cord in the

* Ollivier.

neighborhood of the dorsal and lumbar vertebræ, or the total destruction of it below the last cervical vertebra, has been found entirely to change the qualities of the urine, which has become perfectly limpid, like water, containing little or no animal extractive matter, but much saline and acid principles. The destruction of the medulla oblongata, and of the cervical portion of the cord, has occasioned an immediate suspension of the urinary function, though respiration was maintained by artificial means. Chronic affections of the cord are sometimes accompanied by a morbid state of the bladder; as, chronic inflammation, or a copious secretion of vesical mucus. It has also been remarked, that paraplegia is a disease which, of all others, is most apt to occasion saline incrustations on sounds, left in the bladder.

According to some physiologists, the spinal marrow presides over the functions of *nutrition*. Rachetti* remarks, that the energy of nutrition in animals, is in the inverse ratio to the mass of the brain, and in the direct proportion to the volume of the spinal marrow. It is owing to the predominance of this part of the nervous system, according to the same physiologist, that the crustacea, insects, and worms, owe the remarkable property which they possess, of reproducing parts which have been removed or accidentally destroyed.

The numerous connections of the spinal marrow with the great sympathetic, which has been generally considered as the nervous system of organic or vegetative life, strengthen the opinion, that the former exercises some influence upon the organic functions. The connections of the great sympathetic and the spinal marrow, are so intimate, as to have led some physiologists to the opinion, that this nerve has its origin in the spinal marrow, or derives from the latter the greater part of its nervous energy; and, in confirmation of this opinion, it has been observed, that the developement of the great sympathetic, in different

* Ollivier.

classes of animals, is always in the direct ratio to that of the spinal marrow. On the whole, it may be observed, that of all parts of the nervous system, the spinal marrow is most indispensable to life.

Of the Nerves.

It has already been observed, that there are forty-three pairs of nerves which originate from the cerebro-spinal system, viz. two from the cerebrum, five from the pons Varolii, five from the medulla oblongata, and the remaining thirty-one from the vertebral spinal column. The structure of these cords has already been described.

The cerebro-spinal nerves are subservient to sensation and motion; some of them to one of these functions only, the others to both. Thus the nerves of sight, hearing, smell, are nerves of sensation only; the oculo-motory, the trochlearis, the abducens, and some branches of the fifth pair, and the facial, are nerves of motion. But, with these exceptions, the nerves are both sensitive and motive; or, as the German physiologists express it, *indifferent*.

In their peripheral extremities, the nerves either retain their distinct and independent character, as is the fact with the optic acustic, &c.; or they become amalgamated with the other tissues. The more highly a nerve is endowed with power, the more independent and isolated it is from the other soft parts. Thus, the nerves of specific sensation, as the olfactory, the acustic, and the optic, preserve their individuality in their peripheral expansions. While the nerves of common sensation, as those of the skin, are confounded and melted, as it were, with the tissue of this membrane, so as not to be separable or distinguishable from it. The periphery of the nervous system, however, is not confined to the outer skin, or the external parts of the body, but exists every where, where nerves are expanded, as in the muscles, the parenchyma of most of the organs, and some of the membranes.

Cranial Nerves.

The nerves, which originate from the base of the brain are twelve pairs, and are called cerebral or cranial nerves; the remaining thirty-one, which arise from the spinal marrow, are termed vertebral nerves. Of the cranial nerves, some are possessed of specific sensibility, as the *olfactory*, the *optic*, and the *auditory*. There are others subservient to voluntary motion, as the *third*, the *fourth*, the *sixth*, perhaps the *seventh*, and the *eleventh;* and a third class, whose functions are of a mixed character, as the *fifth*, the *tenth*, and perhaps the *ninth*, or the *glosso-pharyngeal*.

1. *Nerves of specific sensation.*—These are the *first*, *second*, and the *eighth*, or *portio mollis* of the *seventh*.

The first, or the *olfactory* nerve, rises by three roots from the fore and under part of the corpus striatum, and, dividing into numerous fibrils, passes through the foramina of the ethmoid bone, and is distributed on the septum narium, and the adjacent surface of the upper turbinated bone. This is considered as the nerve of smell.

The second, or *optic*, is connected to the optic thalami and the tubercula quadrigemina by two bands, which are extended from these eminences to the optic thalami. The two nerves unite in front of the pituitary fossa, and afterwards separate, and pass through the optic foramina, arrive at the posterior and inner part of the eye-ball, and piercing the sclerotica and choroides, terminate in the retina. This is the nerve of vision.

The *auditory*, or eighth nerve, frequently called the *portio mollis* of the seventh, rises by two roots from the medulla oblongata. It accompanies the facial or the seventh, as long as it is contained in the cranium, and the internal auditory canal. At the bottom of this canal, it divides into branches, which are distributed to the cochlea, vestibule, and semi-circular canals.

These three nerves, together with the fourth pair, are isolated and have no anastomoses. They communicate only with the brain, and the organs to which they are respectively distributed; having no connection with the spinal marrow, nor with the great sympathetic. All the other nerves are connected together by communications, more or less numerous.

2. *Nerves of voluntary motion.*—The cranial nerves, subservient to voluntary motion, are the *third*, the *fourth*, the *sixth*, the *seventh*, and the *eleventh*.

The third pair, or the *motores oculorum*, arise by several filaments from the back part of the crura cerebri. This nerve is distributed to five muscles in the orbit of the eye, and sends a filament to the lenticular ganglion. By this ganglion it communicates with the fifth pair, and with the great sympathetic.

The fourth pair, or the *pathetic*, are the slenderest nerves in the body. Each of these is attached by three or four filaments, beneath the tubercula quadrigemina and the lateral part of the valve of Vieussens. They supply the superior oblique muscle of the eye.

The sixth nerve takes its apparent origin from the outside of the anterior pyramid at the edge of the pons Varolii, and supplies the abductor muscle of the eye. It communicates with the third and the fifth pairs, and by means of these, with all the other nerves, except the four which have been mentioned as isolated from the rest.

The eleventh, or *hypoglossal* nerve, arises from the fore part of the olivary tubercle by several filaments. These are collected together into two fasciculi, which unite to form one nerve. This nerve supplies the flesh of the tongue and several muscles of the throat, on which it bestows the power of motion.

The seventh pair, or *facial* nerve, frequently termed the *portio dura* of the seventh, rises apparently between the corpora olivaria and restiformia. It enters the internal auditory foramen with the acustic nerve, then leaves the latter, and passes out of the cranium by the stylo-mastoid foramen. It receives a

filament of the *Vidian nerve*, which enters the cavity of the tympanum, under the name of the *corda tympani*. The facial nerve furnishes filaments to the muscles of the tympanum, and the integuments of the ear. Upon emerging from the cranium, it enters the parotid gland, and is distributed to the muscles and integuments of the face. The seventh, according to Bell, is a nerve of *instinctive*, but according to Mayo, of *voluntary* motion.

3. *Nerves of a mixed function.*—These are the *fifth*, the *tenth*, and perhaps the *ninth*, and the *twelfth*. The *fifth*, or *trifacial*, are the largest of the cranial nerves. They emerge from the sides of the pons Varolii in two fasciculi or roots, upon the larger of which, or the posterior, is formed a ganglion termed the *Gasserian*. Each nerve afterwards separates into three divisions, viz. the *ophthalmic*, the *superior maxillary*, and the *inferior maxillary*.

The first branch is distributed to the eye-ball, the iris, the lachrymal gland, the schneiderian membrane, and the muscles and integuments of the forehead.

The second division, or the superior maxillary, is distributed to the schneiderian membrane, to the cheek, the nostrils, the palate, and the alveoli of the upper jaw.

The third division, or the inferior maxillary, is distributed to the alveoli of the lower jaw, the submaxillary, and sublingual glands, the tongue, the masseter, the pterygoid, the temporal, and the buccinator muscles, and to the integuments of the temple and chin.

The fifth pair communicates with the third, the sixth, the seventh, the eleventh, and with the great sympathetic; forming of itself a kind of sympathetic nerve, by which all parts of the head are connected with each other, and with all other parts of the body.

According to Sir C. Bell, the branches of the fifth pair, which emerge upon the face to supply the muscles and integuments, are, like the spinal nerves subservient to sensation and voluntary motion, jointly; but Mayo contends, that the facial branches of the

fifth are exclusively *sentient nerves;* while the twigs, which supply the masseter, the temporal, the two pterygoids, and the circumflexus palati, derived from the smaller fasciculus of the fifth, which is destitute of a ganglion, are nerves of voluntary motion.

The sentient branches of the fifth, are nerves of *common* sensation, viz. to the face, and to the organs of *specific* sensation the eyes, nostrils, mouth, &c.; but its third branch, the inferior maxillary, furnishes the tongue with a nerve, which is considered as the gustatory nerve, or the peculiar nerve of taste.

The *tenth pair*, or the *pneumo-gastric nerves*, commonly called the eighth pair, arise from the medulla oblongata, immediately beneath the glosso-pharyngeal. They emerge from the cranium through the foramina lacera posteriora, in company with the ninth, or glosso-pharyngeal nerves, and the twelfth, or accessory nerves; and descend on the lateral parts of the neck, with the great sympathetic on the outer side of the primitive carotid, and posterior to the jugular vein. They distribute branches to the larynx, trachea, lungs, pharynx, œsophagus, stomach, duodenum, liver, spleen, and kidneys.

This important nerve establishes the principal connection between the two departments of the nervous system, and is the bond, which unites together the vital, nutritive, and animal functions. It forms a communication between the organs contained in the three great cavities of the body, viz. the brain, heart, lungs, and stomach. With the fifth and the seventh, it constitutes the principal connection between the organs, subjected to the will and those which are not under the control of this principle. In a word, it unites the two lines of Bichat, the animal, and organic. In its whole course it gives twigs to the ganglions, and contributes to form with their own proper filaments, the principal plexuses of this system.

The branches of the pneumo-gastric nerves, which are distributed to the larynx, lungs, œsophagus, and stomach, appear to be nerves both of sensation and of involuntary motion.

The ninth, or *glosso-pharyngeal nerve*, is attached by several filaments in the line which separates the corpora olivaria from the corpora restiformia. These filaments unite into a single cord, which, after its exit from the cranium, sends a filament to the auditory canal, and receives one from the facial, and another from the pneumo-gastric nerve. It furnishes branches to the root of the tongue, and to the upper part of the pharynx, and bestows the power of motion on the muscles of these parts. According to Mayo, the branches sent to the root of the tongue are sentient only, but those distributed to the upper part of the pharynx, are subservient both to sensation and voluntary motion; an opinion founded on the fact, that, on irritating the glosso-pharyngeal nerve in an animal recently killed, the muscular fibres about the pharynx were found to act, but not those of the tongue.

The twelfth pair, or the *accessory nerve of Willis*, arises from the lateral part of the spinal cord in the upper part of the neck, by numerous filaments, then ascends and enters the foramen magnum of the occipital bone, and passes out by the foramen lacerum posterius, with the pneumo-gastric, to which it sends a filament. It furnishes fibrils to the pharynx, but the greater part of it assists the spinal nerves in supplying the sterno-cleido-mastoid, and the Trapezius muscles, on which it bestows the power of motion. It appears, also, to be a nerve of sensation; for, irritating it excites pain, and consequently in its functions, it resembles the spinal nerves.

The Vertebral Nerves.

The vertebral nerves are more uniform in the manner of their origin, and regular in their distribution, than those which originate at the base of the brain. Each vertebral nerve arises by two distinct roots, an anterior and a posterior, and each of these roots is composed of several filaments. The posterior filaments form a ganglion, before they join the anterior to make up the entire spinal nerve. These nerves,

thus springing from two roots, possess the double property of conveying, in opposite directions, sensific and motive impressions. If a vertebral nerve is divided in any part of its course, the parts, to which it is distributed, are deprived both of their sensibility and of their power of motion. But if the two roots are divided separately, different effects are produced. The division of the anterior roots destroys the power of motion of the parts supplied by the nerve, without impairing its sensibility; while the section of the posterior roots, without affecting the power of motion, abolishes the sensibility. Each of these nerves, therefore, consists of two orders of filaments, which perform different offices, one conveying sensific impressions from the parts, to which they are distributed, to the spinal marrow; the other transmitting motive impressions from the cord to the muscles of voluntary motion.

The vertebral nerves, then, are distinguished by the regularity of their origin, and distribution from those which originate at the base of the brain. They differ from the latter, also, in originating by double roots, and in the circumstance, that one of their roots swells out into a ganglion. One of the cranial nerves, and one only, viz. the fifth, resembles the vertebral nerves in these respects. On this account, the fifth pair of cerebral nerves is classed by Sir C. Bell, with the vertebral; and is supposed to resemble them in its functions, as it does in its structure.

From the regularity of their origin and distribution, the spinal nerves, including the fifth cerebral, are termed by Sir C. Bell, the regular, or the symmetrical nerves. They are distributed laterally to the two halves of the body, including both limbs and trunk, are subservient to common sensation, and to voluntary motion, and, as we are instructed by comparative anatomy, are common to every class of animals.

Most of the other encephalic nerves constitute, according to Bell, another system, which he terms the *superadded* or *irregular*, which he considers as forming a complex associated system, subservient to

respiration. Sir C. Bell remarks, that the motions dependent on respiration, extend nearly over the whole body, while they more directly affect the trunk, neck, and face. This is particularly true of respiration when in a state of unusual activity, or while the individual is under the influence of strong passion or emotion. There is, also, a great variety of actions which are connected with respiration, and which require the aid of the respiratory muscles, such as coughing, sneezing, laughing, swallowing, vomiting, and speaking. Now all these actions, though not subservient to respiration, are so connected with this function, that they necessarily require the aid of the muscles of respiration, as well as that of others peculiarly destined to them; and this connexion establishes associations of the respiratory muscles with many others, and extends the influence of respiration over many other functions of the system.

Respiration, also, exists in various degrees of activity. In its ordinary state, and in sleep, it is an involuntary action. But, in many cases, as, e. g. when any obstruction exists to the ordinary movements of inspiration, or when it is intended to perform some voluntary action, which requires the aid of respiration, as smelling or speaking, it requires the aid of volition. In dyspnœa, violent efforts are made to expand the thorax, by elevating the shoulders; and in highly excited respiration, the movements are not confined to the chest, but affect simultaneously the abdomen, thorax, neck, throat, lips and nostrils. It is evident, then, that whatever may be the design of this extensive connexion of respiration with other functions of the system, it must be effected by an association of a great variety of muscles, animated by some common influence; and the nerves concerned in establishing this connexion, are termed by Bell the respiratory nerves, and form a system distinguished from the spinal, by the irregularity of their distribution. They originate, also, from one root only, and are destitute of ganglions at their origin.

These nerves arise very nearly together in a series, from a tract of medullary matter on the side of the medulla oblongata, between the motor and sensitive columns. From this fasciculus, or column, arise in succession, from above downwards, the *portio dura* of the seventh, the *glosso-pharyngeal*, the *par vagum*, or tenth pair, the *spinal-accessory*, and, as Bell thinks, the *phrenic*, and the *external respiratory*. Bell, also, supposes that the branches of the intercostal and lumbar nerves, which influence the intercostal muscles, and the muscles of the abdomen in the act of respiration, are derived from the continuation of the same cord or slip of medullary matter. The respiratory, or superadded system of nerves, therefore, consists of the portio dura of the seventh, or the facial nerve, the tenth or pneumo-gastric, the phrenic, which is distributed to the diaphragm, the spinal-accessory, which supplies the muscles of the shoulder, and the external respiratory, which is spent on the outside of the chest.

Functions of the Sympathetic Nerve.

The functions of the great sympathetic are not known. In the neck, and the canalis caroticus, it furnishes branches to the great vessels, and to the heart; in the chest, branches which are distributed to the viscera of the abdomen, and in the abdomen, others to the pelvic viscera. The same organs, however, are supplied with nerves from the encephalic system. The common opinion seems to be, that the great sympathetic presides over the organic or involuntary functions, as secretion, nutrition, absorption, calorification, &c. It is also supposed to be, as its name imports, the source of the numerous sympathies, which unite the viscera of organic life into one great connected system. By some physiologists, the ganglions of this nerve are supposed to render the organs, which are supplied with nerves from them, independent of the will.

In herbivorous animals, which employ most of their time in eating, the sympathetic nerve is very large,

corresponding with the voluminous viscera of these animals.

The sympathetic is possessed of scarcely any sensibility. Whatever may be the functions of this nerve, every part of the body must be under the influence of its innervation by means of the branches with which the blood-vessels are supplied, and which penetrate with them into the interior of all the organs.

CHAPTER XIV.

The Circulation.

THE circulation of the blood is another of the *vital functions*, or one which is immediately necessary to life. The universal suspension of it throughout the body, is instantly fatal. Hence, diseases of the heart, and of the great vessels, are apt to terminate in sudden death, while morbid affections of the other vital organs, the brain and the lungs, however violent and acute, scarcely ever, if ever, occasion immediate death.

Life, or vital excitement, is maintained in all the organs by the presence of arterial blood. This fluid is the source of the nutrition of all the organs and tissues, and its presence is an indispensable condition to the performance of every function of the system. If an organ is deprived of arterial blood, from that moment its nutrition ceases, and it loses the power of executing its peculiar functions; and it is obvious that an universal suspension of the circulation, which distributes the blood to every part of the system, must instantly abolish every function of life.

The circulation does not exist in all animals, but only in those, in which the alimentary matter is ab-

sorbed into the system, instead of being *immediately* employed in nourishing it, are first converted into a distinct fluid, the blood, which furnishes the immediate elements of nutrition; and in which, also, there exists a *local* respiration; i. e. the absorption of air takes place separately from that of the other nutritive principles, and, in a separate organ, or apparatus. Two different kinds of matter are absolutely necessary to the nutrition of animals, viz. air, and certain solid and liquid substances, which are called food. The latter, or the food, is not capable of being converted into blood, before the former, i. e. the air, has acted upon it, by one of its principles, oxygen. Now, if these two elements of the blood are not introduced into the system in the same place, but by separate organs, it is evidently impossible, that they can, immediately after their absorption, be employed in nutrition. It is necessary that one of them, after its absorption, be conveyed to the organ where the other is absorbed, and that the nutritive fluid, formed by their mutual action, be afterwards carried from this organ to all parts of the body, to furnish the materials for their nutrition, and vital excitation. Hence, a local respiration is always accompanied with a circulation; while in those animals, in which respiration is disseminated, i. e. is not concentrated in a particular organ, as in insects, there is no circulation.*

The organs of the circulation are the *heart*, the *arteries*, the *veins*, and the *capillary vessels*. These organs, collectively, represent two trees of unequal size, whose trunks are united at the heart, and whose branches are infinitely ramified; those of the larger tree, throughout all parts of the system; and those of the smaller, throughout the lungs. At the union of the two trunks is found the central organ of the circulation, the heart.

The motion of the blood in this apparatus is a circulatory one. This fluid is forced out of the heart by the contraction of the organ, and propelled to every

* Adelon.

part of the body through elastic tubes, called arteries. From the extremities of these it passes into the minute organs of another set of tubes, termed veins, and by them is returned to the heart. According to some physiologists, there exists between the termination of the arteries and the commencement of the veins, an intermediate order of fine hair-like vessels, termed capillaries. The course of the blood from, and to the heart, is called the circulation.

The Heart.—In the human species, in that class of the animal kingdom called the mammalia, and in birds, the heart is a double organ, consisting, in fact, of two single hearts, each of which gives motion to a distinct species of blood. One of them receives the dark venous blood which returns from all parts of the body, and transmits it to the lungs, where it is converted by respiration into scarlet-colored arterial blood. This may be termed the *venous*, or the pulmonary heart. The other heart receives from the lungs the arterial blood, and conveys it to all parts of the system. This may be called the *arterial* or *aortic* heart. And these two hearts are riveted together into a single organ. Each of these two hearts contains two cavities, one designed to receive the returning blood from the veins; the other, to propel it in the opposite direction into the arteries, and through them, to all parts of the body. The cavities, by which the heart receives the blood, are called *auricles;* and those which contract upon this fluid and force it out of the heart into the arteries, are termed the *ventricles.* The walls of the heart are composed of a muscular substance, the fibres of which run in various directions, interlacing one another, and forming an inextricable tissue. The parietes of the ventricles are much thicker than those of the auricles. The cavities are lined by a thin membrane, forming, by its folds, valves which sentinel the different apertures and outlets of the organ.

The heart is covered externally by a serous membrane, reflected over it from the pericardium, a sac of a fibro-serous structure. This membrane secretes a

fluid called the *liquor pericardii*, the use of which is to lubricate the organ.

The nerves of the heart are derived from a plexus formed by filaments of the pneumo-gastric and the great sympathetic nerves, and they follow the ramifications of the coronary arteries.

The heart is situated in the thorax, in the lower part of the anterior mediastinum. Its position is oblique, being inclined forwards, downwards, and outwards, and from right to left. Its posterior surface is nearly horizontal, and rests upon the aponeurotic centre of the diaphragm. Its anterior is turned a little upwards, and exhibits a groove passing from left to right obliquely downwards, in which is lodged the anterior coronary artery and veins. The base of the organ is directed backwards, and to the right towards the bodies of the dorsal vertebræ, from which it is separated by the aorta and the œsophagus. The apex is inclined forwards and to the left, and during life its pulsations are felt between the cartilages of the fifth and sixth ribs.

The figure of the heart is somewhat conical. The septum which separates its cavities, runs in the direction of its long axis, but in such a manner that the apex of the heart falls exclusively to the left ventricle. The chambers of the *pulmonary* or *venous* heart, more usually termed the *right* side of the heart, are triangular in their shape; while those of the *arterial*, which is also called the *left* side of the heart, are oval. Each of these cavities is capable of containing about two ounces of blood. The two auricles are so connected by their common septum, and by fibres passing from one to the other, that it is impossible for either to contract alone. The same is true of the two ventricles. They have a common septum, and there are whole layers of fibres common to both. On the contrary, the auricles and ventricles are connected with each other only by cellular tissue, vessels, and nerves. No muscular fibres pass from one to the other, and by maceration they may be easily separated from each other.

According to some physiologists, the right ventricle has a greater capacity than the left, because the venous system to which it belongs, is more capacious than the arterial. But others assert, that the superior capacity of the right side of the heart, is a cadaveric phenomenon, owing to the accumulation of blood in it, which occurs in the last moments of life; while the left side, in a state of vacuity, contracts to a smaller volume.

Each cavity of the heart is lined with a thin transparent membrane, which is continued from the ventricles into the corresponding arteries, and from the auricles into the veins which open into them. It is usually classed with the serous membranes.

Between each auricle and the corresponding ventricle is placed a valve, which is formed by a duplication of the inner membrane, strengthened by intervening fibrous substance. The free margin of these valves is irregular, and in the right side of the heart it presents three apices, but two only in the left. Whence the right auriculo-ventricular valve is termed the *tricuspid* valve, and the left, the *bicuspid* or *mitral*. The floating edge of the valves is attached to the fleshy columns of the ventricles by short tendinous threads, called *chordæ tendineæ*. The margin of the valves is strengthened by little granular bodies, termed *corpora sesamordea*. These valves prevent the refluence of the blood from the ventricles into the auricles, during the contraction of the former.

Valves exist, also, at the origin of the two great arteries, the pulmonary artery, and the aorta, where these vessels communicate with the right and the left ventricles. These valves differ widely from the former. They are formed by folds of the inner membrane of the arteries, are of a semi-lunar shape, and are attached by their convex margin to the circumference of the artery, each occupying a third part of it. These are termed the semi-lunar, or sigmoid valves, and their office is to prevent a reflux of the blood from the aorta and pulmonary artery, into the corresponding ventricles.

The orifice of the inferior vena cava is also furnished with a duplication of its inner membrane, which projects into the cavity of the auricle, and is called the Eustachian valve. This valve is useful only in the fetal state, and its office is to direct the blood of the inferior cava through the *foramen ovale*, an aperture by which, during fetal life, the two auricles communicate with each other. This aperture closes after birth, leaving an oval depression in the septum of the auricle, termed the *fossa ovalis*.

At the opening of the coronary vein, also, a valve is found formed by a semilunar fold of membrane, and which prevents the reflux of blood from the auricle into the vein. There are no valves at the entrance of the superior cava into the right auricle, nor of the pulmonary veins into the left.

The Arteries.—The vessels into which the blood is propelled by the action of the heart, and distributed to all parts of the body, are termed arteries. These vessels form two distinct systems, the aortal and the pulmonary; the former connected with the left, the latter with the right ventricle of the heart. The main trunk of the aortal system, which opens into the left ventricle, is called the aorta. It contains scarlet colored blood, which it distributes by its ramifications throughout all parts of the system, terminating in minute twigs at the periphery of the body, and in the limbs and internal organs. The main trunk of the pulmonary arterial system which arises from the right ventricle, is called the pulmonary artery. It carries dark colored or *venous* blood, and its ramifications are distributed throughout the lungs.

Where an artery divides, its branches have an area greater than that of the trunk, and they generally diverge at acute angles. In general, the arterial and venous trunks are distributed together; the larger arteries having an accompanying vein, the smaller ones, two. The capacity of the venous system is much greater than that of the arterial.

The arteries frequently inosculate with one another, permitting the blood to pass freely from one branch

to another, and these communications increase, as the arteries become more distant from the heart. These vessels are nourished by minute arterial branches, distributed through these tunics, and which are termed *vasa vasorum*. They are also supplied with nerves, which are derived principally from the great sympathetic. The structure of these vessels has already been described.

The Veins.—The *veins*, which return the blood to the heart from all parts of the body, constitute, like the arteries, two systems; one of which corresponds to the arterial system of the aorta, and conveys dark colored or venous blood from the periphery of the body, from the head, trunk and limbs, and from all the internal organs, to the right auricle of the heart, into which it opens by the two great trunks, called the *venæ cavæ*, *superior* and *inferior*. The other, which corresponds to the pulmonary arterial system, conveys scarlet colored or arterial blood from the lungs to the left auricle of the heart, into which it opens by four large trunks, called the pulmonary veins.

The veins are very strong and flexible tubes, though possessed of little elasticity. They are furnished with numerous valves, formed by semilunar folds of thin interior tunic, the office of which is to prevent the reflux of the blood. Like the arteries, they are furnished with vasa vasorum, and with nerves derived from the great sympathetic.

The Capillary Vessels.—*The capillary system*, which is intermediate between the terminations of the arteries and the origins of the veins, presents two modifications. In one, it consists of canals, furnished with proper coats or walls, which carry blood from the extreme arteries into the origins of the veins. But in many parts of the body, the coats of these fine vessels disappear, and the globules of blood find a passage for themselves, in various directions, in the parenchyma of the organs; and these passages at length begin to enlarge, acquire walls, and assume the character of the finest veins. The capillary canals of this species are much smaller than the first, and, it is said, permit only

a single globule of blood to pass out at a time. They are also subject to great changes, some of them disappearing and closing up, and new ones being formed. The formation of these vessels is caused by the fine arterial canals gradually losing their coats, and becoming confounded with the parenchyma of the organs. The capillary vessels have numerous anastomoses, and they are the theatre of the functions of nutrition, secretion, calorification, hematosis, &c.

The capillary system is divided into two sections or departments, one called the *general*, the other the *pulmonary*. The first of these is intermediate, between the ultimate branches of the aorta, and the origins of the venæ cavæ. It is the theatre of nutrition, and secretion, and of the conversion of arterial into venous blood. The second exists only in the lungs, and is intermediate between the pulmonary artery and the pulmonary veins. It is the seat of hematosis, or of the conversion of venous into arterial blood, and may be considered as opposed to the general capillary system, in which the mass of the blood undergoes the opposite changes.

It appears from this, that the lungs have two capillary systems, viz. one connected with their peculiar function, or *respiration;* and another, which is a branch of the general capillary system, and is connected with the *nutrition* of these organs.

Some physiologists do not admit a distinct capillary system. According to Wilbrand, the arteries terminate and are lost in the tissues and organs, and the veins originate anew. Most physiologists, on the contrary, contend for the immediate passage of the arteries into the veins, and Rudolphi asserts that the placenta affords the only exception to this structure. In the invertebrated animals however, or at least in many of them, it is said to be impossible to force injections from the arteries into the veins.

Such is a brief account of the general structure of the heart and blood-vessels, in the human species, the mammalia, and birds. In another class of animals, the reptiles, a part only of the blood passes through

the lungs, to become endued with the arterial principle; these animals being so constituted, that the æration of a portion of the blood is sufficient for the renovation of the whole mass. In the reptiles, therefore, it is not necessary that the two kinds of blood should be kept separate. Indeed, if they were so, the renovated portion could not impart its animating influence to the other. Hence, these animals have only a single heart, consisting of one ventricle, and one or two auricles. The auricle receives both arterial blood from the lungs, and venous blood from all parts of the body; and in its cavity these two kinds of blood are mixed together. From the ventricle arises a single arterial trunk, which divides into two branches, one of which carries a portion of the blood to the lungs, to be subjected to respiration; the other distributes the remaining portion to all parts of the body.

In the other classes of animals, the two kinds of blood are not mixed together, but remain distinct; and, of course, one and the same heart is not sufficient to circulate both. In these classes of animals, comprehending the worms, the mollusca, the crustacea, and fishes, the organs of the circulation present different dispositions. Worms have no heart; and the circulation, which consists in the passage of the blood from the organs of respiration to all parts of the animal, and its return to these organs again, is carried on exclusively by vessels. In the crustacea, and most of the mollusca, there is a single heart only, but it is designed to circulate only *arterial* blood. Its office is limited to the conveying of arterial blood to the various parts of the body; and this blood, after its conversion to venous blood in the different organs, is returned to the organs of respiration by *vessels*. These animals, therefore, possess an *arterial* heart. In the cephalopodes there are three hearts, two venous, and one aortic.

In fishes, also, there exists only a single heart; but this is not designed to circulate both kinds of blood, as in the reptiles, nor arterial blood alone, as in the crustaceous and some of the molluscous animals. Its office

is to propel the venous blood to the gills, while the arterial blood is conveyed from these organs to all parts of the system, not by another heart, but wholly by *vessels*. Fishes, therefore, have properly only a *venous* heart. Their aorta is a vessel formed by arteries, which proceed from the gills.

The Circulation.

It has already been observed, that the heart is a double organ, being composed of two distinct hearts united together. Each of these is the organ of a distinct circulation. One of them, viz. the arterial heart, is the agent of the greater, or the *general* circulation; the other, or the venous heart, is the organ of the lesser, or the pulmonary. In the general circulation, in which the course of the blood forms a larger circle, arterial blood is projected from the arterial heart, through the aorta and its branches, to all parts of the body, and, having lost its arterial character in the various organs, is returned as venous blood, to the pulmonary or venous heart. The venous heart is the origin or point of departure of the lesser or pulmonary circulation, which forms a much smaller circle than the aortic. It consists in the passage of the venous blood, through the lungs, where it loses its venous character by the influence of respiration; and in its return from the lungs, as arterial blood, to the arterial or aortic heart.

Beginning at any given point in the circulation, as, e. g. at the auricle of the pulmonary or venous heart, the course of the blood is as follows. The pulmonary auricle receives the venous blood on its return from all parts of the system. From the auricle it passes into the corresponding ventricle, by the contraction of which it is projected into the pulmonary artery, and by the ramifications of this vessel is conveyed to the capillary system of the lungs. Here it loses its venous character, and is converted into arterial blood. It is then taken up by the pulmonary veins, and conveyed to the auricle of the arterial heart, and thence into the

corresponding ventricle, by the contraction of which it is projected into the aorta, and by the ramifications of this vessel distributed to all parts of the system. In the capillary vessels of these it loses its arterial character, and then passes into another system of vessels, the veins, by which it is returned as venous blood to the auricle of the pulmonary heart, from which its course was supposed to commence.

It appears from this, that neither circulation is quite complete; for, in neither does the blood return to the same point from which its course commenced. In order to arrive at this point, wherever it be assumed, the blood must pass the round of both circulations, arterial and pulmonary, and undergo both of the changes which are effected in the capillary systems of the two, i. e. the change from arterial to venous, and that from venous to arterial blood. It appears, then, that the two parts of which the heart is composed are so related to each other, that the ventricle of one forms the commencement, and the auricle of the other the termination, of a distinct circulation. The heart has the lungs between its right ventricle and its left auricle; and all the organs of the body, including the lungs and the heart itself, between its left ventricle and its right auricle. The right ventricle and the left auricle, therefore, are the two extremes, between which is comprehended the pulmonary or lesser circulation; while the left ventricle and the right auricle bound the arterial or the greater circulation.

Besides this division of the circulation into aortal and pulmonary, or greater and lesser, another was proposed by Bichat, founded on the qualities of the blood, and the changes which it undergoes in the lungs, and the general capillary system. Bichat divides the circulation into arterial and venous, or the circulation of red, and that of black blood. In the first, the blood passes from the lungs to all parts of the body; in the second, it returns from all parts of the body to the lungs again. According to this view, the circulation may be reduced to two phenomena, viz. the passage of the blood from the ca-

pillaries of the lungs where it assumes its arterial properties, to the general capillary system where it furnishes the elements of nutrition and of the secretions, and acts as the universal excitant of all the organs; and, secondly, the passage of the blood from the general capillary system to the pulmonary capillaries, where the properties of the vital fluid are renovated by respiration. In this view, the two capillary systems, the general and the pulmonary, are the points of departure of the two circulations, instead of the aortal and pulmonary sides of the heart.

The circulation of red blood commences in the capillary system of the lungs, where the blood acquires the peculiar characters which distinguish arterial blood. From the capillary system of the lungs it passes into the pulmonary veins, which convey it into the left auricle, or that of the arterial heart. From this it passes into the corresponding ventricle, which projects it into the aortal system. Through this it is distributed to the general capillary system, which may be considered as the termination of the circulation of red or arterial blood. In this, then, the arterial blood is constantly passing from the capillary system of the lungs, to the general capillary system; and, in its passage, it is transmitted through the arterial heart, or what is commonly called the left side of the heart. The whole of the left side of the heart, therefore, belongs to the circulation of arterial blood.

The circulation of the black, or venous blood, commences where the former terminated, i. e. in the general capillary system. Here the blood is converted from arterial into venous, from scarlet to purple-colored blood. From the general capillary system it passes into the veins, which convey it to the pulmonary or venous heart. From this it is distributed by the pulmonary artery to the capillary system of the lungs, which is the termination of the circulation of venous blood. This circulation, then, consists in the passage of venous blood, from the general capillary system to that of the lungs, in the course of which it passes through the pulmonary or venous heart. The whole

of this side of the heart, therefore, belongs to the circulation of venous blood. Each of these circulations begins with veins, and terminates with arteries, and each of them, in its course, passes through both cavities of one side of the heart. Each of them consists of two segments of circles of unequal size; the larger being a moiety of the general or aortal circulation, the smaller, a division of the pulmonary. The circulation of red or arterial blood, consists of the venous part of the pulmonary, and of the arterial part of the general circulation; and the circulation of venous, or purple blood, consists of the venous segment of the aortal or general circulation, and of the arterial segment of the pulmonary.

The two circulations are entirely independent of each other, except at their origins and terminations, the two capillary systems, where the arterial and venous blood are reciprocally transformed into each other; and they intersect each other at the heart, through which they both pass, yet without communicating together.

In the circulation of red, or arterial blood, the vital fluid is sent to the general capillaries, and traverses all the organs, furnishing in its passage the elements of nutrition, and of the secretions. It, also, communicates to all the organs a peculiar species of vital impulse, or excitation, indispensable to life and to the functions of the organs. A part of the arterial blood remains in the organs, to replace the materials removed by vital decomposition; another part is expended in the secreted fluids, and passes into the canals belonging to this function in the different secretory organs. Of course, a part only, and perhaps but a small part of the blood, returns to the heart, robbed of its vital and nutritious principles, and presenting the characters of venous blood. The first impulse of the blood in this circulation, is received in the capillary vessels of the lungs, but its principal moving power is the left ventricle of the heart.

In the circulation of black or venous blood, this fluid passes from the general capillary system to that

of the lungs, in order to be renovated and converted again into arterial blood by respiration. In its passage to the pulmonary heart, it is reinforced by the addition of a considerable quantity of chyle and lymph, which are on their way to the lungs, to be converted into blood by respiration. These two fluids, the chyle and lymph, are gathered up and conveyed into the blood by an order of vessels called absorbents. These vessels, collecting the materials of renovation from the organs, by vital decomposition, and from all the free surfaces of the body, internal and external, convey them by two principal trunks into the great veins, near the heart. These materials are unfit for the purposes of the economy, some of them by defect of animalization, others, perhaps, by an excess of it. They are, therefore, blended together, and mixed with the venous blood, with which they are transmitted through the lungs, where the whole compound fluid is converted by respiration into arterial blood. The venous blood appears to owe its principal characters to an excess of carbonic acid, and, perhaps, to the loss of oxygen, expended in nutrition and the secretions. In asphyxia from carbonic acid, the blood is said to be much darker than in asphyxia from other causes. The motion of the venous blood is first impressed by the action of the general capillaries, which forces the vital fluid into the radicles of the veins, where it clears the first set of valves. These sustain the column of blood, and prevent its retrograding, when the veins, excited by the stimulus of the blood, contract upon it, and force it beyond the next series of valves. When it reaches the pulmonary heart, it receives a new impulse by the contraction of the right ventricle.

The passage of the blood through the two capillary systems, may be considered as constituting a distinct circulation, which may be termed the *capillary*.

This may be divided into two kinds, viz. the *general*, and the *pulmonary* capillary circulation. In the former, the blood furnishes the organs with the materials of nutrition, and of the secretions; caloric is evolved, the blood becomes charged with carbonic

acid, and perhaps loses some of the oxygen it had acquired in respiration, and is converted from arterial into venous blood.

The capillary circulation of the lungs may be considered as opposed to the former. It has, for its object, the renovation of the blood, or its conversion from venous to arterial, by respiration; an effect which seems to be produced by the loss of carbonic acid, and the acquisition of oxygen.

The capillary circulation possesses no central organ of impulsion, like the two others, but depends on the vital contractility of the minute vessels, which execute it; and it does not present the same regularity as the cardiac circulation. In the normal state, the general sum of its activity remains nearly the same; since the same quantity of blood must traverse the capillary system in a given time. But the activity of particular parts of it may be much increased or diminished. By increasing it in one place we may lessen it in another, and vice versâ; a principle, on which depends the effect of counter-irritation. The capillary circulation survives the cardiac, and is the last to cease at death.

Admitting the existence of the capillary system, animals may be said to possess two circulatory systems; one a *peripheral*, which constitutes a circle, the other, a *central*, which forms the radii of this. The lower we descend in the zoological scale, the more the peripheral or capillary predominates; and the higher we ascend, the more does the central or cardiac. Hence, the more easy re-establishment of the circulation in the lower than in the higher animals, after the ligature of large arteries; the circulation being then maintained by the numerous anastomoses of the peripheral system.

Mechanism of the Circulation.

The motion of the blood is maintained principally by the action of the heart. This organ is endued with great irritability, in consequence of which it

contracts with great force upon the blood, which flows into it from the veins, and propels it into the mouths of the great arteries, which communicate with its ventricles.

The action of the heart consists of an alternate contraction and dilatation, or systole and diastole, of the auricles and ventricles. When the auricles receive the blood returned from the general circulation and the lungs, by the venæ cavæ and the pulmonary veins, they contract upon it and force it into the ventricles, which dilate at the same moment to receive it; and immediately afterwards, when the distended ventricles are contracting to force the blood into the aorta and the pulmonary artery, the auricles dilate in order to receive a new supply from the veins. Hence the contraction of the auricles and the dilatation of the ventricles, take place at the same time, and vice versâ. The two auricles contract, and dilate, simultaneously, and the same is true of the two ventricles. This is probably owing to the fact that the two auricles have a common muscular septum, so that one cannot contract without the other; a structure, which exists also in the ventricles; while the auricles are connected to the ventricles only by cellular tissue, vessels, and nerves.

When the auricles contract, the blood expelled by their action is thrown back partly upon the veins, producing, in some cases, a venous pulse; but the greater part of it enters the ventricles, which spontaneously dilate to receive it. A pulse in the jugular veins is sometimes perceptible in persons of spare habits, and in morbid affections of the lungs, owing to a reflux of blood into these veins at the time of the contraction of the right ventricle. In some cases this reflux extends to the veins of the liver, producing an engorgement of this organ. So, where there is an obstacle to the passage of the blood into the aorta, there is sometimes a reflux into the pulmonary veins, by which the lungs become engorged.

The action of the auricles is gentle, and is sometimes repeated before the contraction of the ventricles

takes place. The action of the ventricles is sudden and powerful. The dilatation of the ventricles occupies thrice as much time as the contraction. According to some physiologists, during the contraction of the auricles, one of the tricuspid valves closes the orifice of the pulmonary artery, and one of the bicuspid that of the aorta, so as to prevent the entrance of the blood into these vessels, during the dilatation of the ventricles.

The right auricle has more fleshy columns than the left, to enable it more thoroughly to blend together the chyle, the lymph, and the venous blood.

The systole of the auricles is succeeded by that of the ventricles, during which the tissue of the heart hardens and shortens itself, is displaced a little, and its apex curls upwards and strikes the left wall of the chest, between the sixth and seventh ribs. This phenomenon has been referred to the impulse, which the aorta and pulmonary artery receive from the wave of blood projected into them, which displaces them a little, and produces a reaction upon the heart, by which the point of the organ is pushed forward and to the left. The dilatation of the auricles also, which takes place during the contraction of the ventricles, must contribute to carry the latter forwards. It appears, however, that these circumstances are not necessary to produce this effect; for if the heart of an animal recently killed, be placed, while yet palpitating, upon a table, the apex continues to be tilted up by each contraction of the ventricles.

The walls of the left ventricle are thicker and stronger than those of the right, because it has a greater distance to project the blood; and according to Berthold, the right ventricle has a greater capacity than the left, because the venous system, to which it belongs, is more capacious than the arterial. By the systole of the ventricles, the blood is projected with great force and velocity into the aorta and pulmonary artery, and, through these canals, distributed throughout the general system and the lungs. It is then taken up by the radicles of the corresponding veins, and

returned by the trunks of these vessels to the auricles of the heart. The motion of the blood is more rapid, as the arteries are larger and nearer the heart. Its velocity gradually diminishes as the arterial canals become smaller, and recede farther from the heart, as appears from the feeble jets of blood emitted by the small arteries. In arteries of a certain degree of minuteness the jets disappear; a fact which proves, that the force of the heart is much lessened in these remote vessels. This gradual retardation of the velocity of the blood is owing, partly, to the increasing resistances which this fluid has to encounter in its passage through the arterial tubes, from friction and other causes, and partly to the increasing capacity of the vessels as they become more distant from the heart. In the veins, on the other hand, the blood moves with a constantly accelerated velocity, towards the heart.

The course of the blood in the arteries is an intermittent one. It is alternately more and less rapid; more so during the systole of the heart, because then the blood moves under the influence of the most powerful of the moving forces; less rapid during the diastole, because it then moves only under the contractile reaction of the arteries. In the first moment it flows by jets, which coincide with the contraction of the ventricles, and which are greater, as the artery is nearer the heart. In the second, it flows from an open vessel in a continued stream, in consequence of the reaction of the arterial walls. The blood, which flows from an artery between the jets, issues out by the elasticity of the arterial tunics.

Attempts have been made to compute the force with which the ventricles of the heart contract. Hales estimated the force exerted by the left ventricle of a horse, in propelling the blood, at 113. 22 pounds, and that which is exerted by the left ventricle of a man's heart, at 51. 5 pounds. According to Le Pelletier, the systole of the left ventricle overcomes the whole pressure of the atmosphere upon the body, equal to 35,000 or 40,000 pounds. The resistance, which the

systole of the heart has to overcome, arises from the inertia of the mass of blood which it propels, and the friction of this fluid against the walls of the vessels, through which it passes.

The whole quantity of the blood in the body of an adult, is estimated at between thirty and forty pounds, and this, it is computed, performs more than five hundred and fifty revolutions through the body every twenty-four hours. A complete revolution of the blood, it is estimated, is accomplished in about three minutes. The contractions of the ventricles take place at equal intervals, and in adults from seventy to seventy-five times in a minute. In new-born infants, the heart contracts about one hundred and forty times in a minute, a rate which gradually diminishes until the period of adult age. In old age, the contractions of the heart diminish in frequency, the pulse not exceeding sixty in a minute.

Moving Powers of the Circulation.

Some physiologists, as Harvey, Haller, and Spallanzani, consider the heart as the only moving power of the circulation.

Others, as Hunter, Blumenbach, Sæmmering, Senac Martini, &c. are of opinion, that, besides the propelling force of the heart, a muscular contractility of the arteries, is one of the moving forces of the circulation.

A third class, including Bichat, Weitbrecht, and Darwin, deny that the arteries possess an active power of contracting; but they assume a vital contractility in the capillary vessels, a kind of absorbing and propelling force, which moves the blood in the capillary system, which they consider as removed from the influence of the heart.

There is another class, among whom are Treviranus, Carus, and some others, who ascribe the motion of the blood, chiefly, to a self-moving power existing in the blood itself, while they consider the heart as only an auxiliary force, and deny all power to the arteries and the capillary vessels.

Another opinion, almost as singular, is that of Burns, who regards the arteries as the principal moving powers of the circulation, while he limits the office of the heart merely to the regular delivery of the blood to the aorta, to be afterwards distributed by the contractions of the arteries to all parts of the system. Burns' opinion is founded on a phenomenon, which he alleges is often observed in patients, affected with ossification of the aortal valves. He says, that it is a well known fact, that, in this disease, the heart sometimes contracts twice for each pulsation of the arteries, which he affirms could not happen, if the heart propelled the blood through the arterial system by its own unassisted powers. For, in that case, the arterial pulsations being the effect of the contractions of the heart, would necessarily, in every instance, exactly synchronize with the latter, and could in no case be either more or less. The phenomenon, he says, may be easily explained, by considering, that, when the aortal valves become rigid by ossification, they oppose an obstacle to the free passage of the blood from the heart to the aorta; so that a sufficient quantity of blood is not projected into the artery, by a single contraction of the heart, to fill the vessel; and the latter, consequently, does not react upon the blood, until it receives an additional supply by a second contraction of the heart.

These opinions we shall not stop to examine, but shall proceed to consider the functions of the different parts of the circulatory apparatus.

Functions of the Heart.—The heart is the principal moving power of the circulation; a doctrine which rests on many facts and considerations. One of these is the astonishing irritability of the heart. When this organ is removed from the thorax of a living animal, as, e. g. a frog, and put into warm water, it will continue to contract and dilate with great energy, throwing jets of the fluid to some distance for a considerable time. It even exerts this self-moving power, when empty, and placed in a vacuum, so that its action is independent of the contact of air and blood.

In some animals, particularly in some of the reptiles and fishes, the heart retains this power of contracting some time after death. The heart of a snake has responded to very active irritation, four days after the death of the animal. The heart of a sturgeon was cut out and laid on the ground, and after it ceased to beat was blown up, in order to be dried. It was then hung up, when it began to move again, and continued to pulsate regularly, though more slowly, for ten hours; and it even continued to contract, where the auricles had become so dry, as to *rustle with the motion.** Mayo states, that if the heart be taken from the body of an animal immediately after death, and the blood be carefully washed from its internal surface, or, if the auricular portion be separated from the ventricles by a clean section, the alternate states of action and relaxation continue to recur as before; and for a short period, no stimulus seems to be required to excite it to contract. The alternation of action and repose, Mayo remarks, seems to be natural to its irritable fibre, or to result immediately from its structure.

Nothing of this kind is observed in the arteries. They never undergo the alternate contractions and dilatations, which are observed in the heart taken from a living animal; but they are uniformly found contracted upon themselves. Nor do irritations applied to them excite them to contraction, after death. If the finger be inserted into the open aorta, it does not feel itself compressed by the contraction of the vessel, as it does, when thrust into the heart.

If an arm of a dead body be cut off, and immersed some time in a warm bath to make it pliable, and a small tube be then fixed by one extremity in the brachial artery, and by the other in the open carotid of a large living dog, the heart of the animal will instantly drive blood into the lifeless arm, and produce a feeble pulsation in the artery. So if several inches of an artery be cut out, and the continuity of the canal be re-established by a metallic tube, the portion of the

* Mitchell, Am. Journ. Med. Scien. No. 13.

artery beyond the tube will pulsate just as if the vessel had remained entire. Bichat observes, that if the arteries give rise to the pulse by their own powers of contraction, there ought to be a defect or irregularity in the arterial pulsations below an aneurismal tumor; since the arterial texture, being altered and partly destroyed, it must necessarily lose its living powers, and, consequently, its vital contractility. Bichat further observes, that the jets of blood from an open artery, correspond with the dilatation of these vessels, and the subsiding of the jets, with their contraction; which is exactly the reverse of what we should expect, if the pulsations were occasioned by the action of the arteries themselves. On the whole, there can be no doubt, that the pulse is occasioned by the systole of the heart, and not by the action of the arteries themselves. The pulse, in all parts of the body, is exactly synchronous with the systole of the ventricles.

According to Dr. Young, the velocity of the pulsations is sixteen feet in a second, which would diffuse them simultaneously throughout every part of the system. The pulse seems to be caused, not by the dilatation of the arteries, but by a slight movement of locomotion, or vibration, occasioned by the stroke of the ventricles and simultaneous with it, followed by reaction of the arterial coats upon the column of blood. This occupies the interval between the pulsations. Even when ossified and incapable of being dilated, it is said that they still pulsate. Sometimes the aorta forms a long bony tube, yet the pulse is not obliterated. No pulse exists in animals destitute of a heart.

Functions of the Arteries.—The only power which the arteries exert in the circulation, according to Bichat, is the physical property of elasticity or contractility of tissue. In his view of the circulation, the power of the heart projects the blood into the arteries, which at first yield, though very little, to the impulse; but, as the blood advances farther on in the arterial system, the part of the latter nearest the heart, which was first dilated, being relieved of the

distension, contracts by its elasticity upon the decreasing column of blood. In this view the contractile power of the arteries, merely serves the purpose of adapting their capacity to the volume of their contents, and, in short, of keeping the arteries constantly full, whatever may be the quantity of blood which they contain. And if we keep in mind the fact, that the arteries, notwithstanding the perpetually varying quantity of their blood, are constantly full, it is easy to conceive that the contraction of the left ventricle, forcing an additional quantity of blood into them, will be felt, at the instant it takes place, throughout the whole arterial system; and that a quantity of blood, equal to that which is propelled into the aorta by each contraction of the left ventricle, will be removed by the same stroke from the further extremity of the arterial system. If the arteries of a dead body be injected with water, and a syringe filled with the same fluid be fixed in the aorta, at the moment the piston of the syringe is pressed down, the water will spirt out of any artery that happens to be open, no matter how remote it may be from the propelling force. In this view, the contraction of the arteries contributes not a particle of power to the circulation, but merely serves to keep the arterial tubes constantly full, by adapting their capacity to the volume of their contents.

Many facts, however, are inconsistent with this doctrine, and tend to prove that the arteries are endued, not merely with the physical property of *elasticity*, but with a *vital* power of *contractility*, by which they contribute to the sum of the moving forces of the circulation.

1. If the carotid artery of a living animal be laid bare for a few inches, and two ligatures be applied to it at some distance from each other, on making a small incision into the artery between the ligatures, the blood will immediately spirt out with considerable force, and the artery become much contracted. As, in this experiment, the force of the heart is intercepted by the lower ligature, the blood must be forced out of the

artery by its own contractile power. If the experiment be performed after death, the blood, instead of spirting out to some distance, will flow out with little or no jet.

Magendie compressed with his fingers the crural artery, in a dog, and saw it contract below the pressure, so as to expel from its cavity all the blood it contained.

2. In hemorrhage, the bleeding arteries contract in proportion to the loss of blood; but if the hemorrhage prove fatal, the same vessels return to their original dimensions. Their contraction, in the first instance, is evidently not owing to elasticity, but must be of a vital character, because, after death it ceases, and the arteries become enlarged, and resume their original diameters.

3. Arteries may be influenced by stimulants applied to their nerves. Philip found that the motion of the blood, in the capillary system, was influenced by stimulants applied to the brain. But Sir E. Home ascertained that even the large arteries were capable of being excited, by irritating the nerves which supplied them. He separated by a probe the par vagum, and the sympathetic nerve, from the carotid artery, in dogs and rabbits; and then, touching these nerves with caustic alkali, in one minute and a half he observed the pulsations of the artery gradually to increase, and in two minutes, to become still stronger. In another experiment he wrapped the wrist of one man in ice, and enveloped that of another in cloths dipped in hot water; in consequence of which, in the first individual, the pulse in the wrist operated on, became stronger than that of the opposite wrist; and in the second, weaker.

4. The shrinking of arteries, from exposure to the air, demonstrates a power of contraction in them, different from mere elasticity, and which must be of a vital character. Dr. Parry found that the artery of a living animal, if exposed to the air, would sometimes contract in a few minutes to a great extent; and in some

instances, only a single fibre of the artery was affected, narrowing the channel of the vessel, as if a string were tied round it.

5. Hoffman observes, that in paralytic limbs, there is, in many instances, no pulse, although the power of the heart is unimpaired; and, according to Martini, Nassius relates the case of a man, who died in a fit of syncope, in which a very sensible pulsation of the arteries, continued a quarter of an hour after the motion of the heart was entirely extinct.

6. A fact mentioned by Laennec, and which has probably been observed by many other physicians, is worthy of notice in this place. This eminent pathologist asserts, that, in diseases of the heart, the pulse is often feeble, and indeed almost imperceptible, although the contractions of the heart, and especially those of the left ventricle, are much more energetic than usual. In apoplexy, on the contrary, the pulse is frequently strong, when the impulse or contraction of the heart is very feeble; facts which, according to Laennec, seem to be inexplicable, except by supposing that the arteries act independently of the heart.

7. Further; cases have occurred, though very rarely, in which the pulsations of the arteries did not correspond with the systole of the heart. The instances referred to by Burns, are of this description. According to Rudolphi, Zimmerman saw a woman, in whose right arm the artery generally beat only fifty-five strokes, while that of the left beat ninety or ninety-two. A venerable medical friend mentioned to the author a similar case, which he had witnessed himself. On this subject Martini makes the following remark: "Ad hoc arteriarum micatus sæpenumero frequentiores deprehenduntur, quin cordis motus nihilum quidem increverint." The same author further states the following fact: "Corde osseam firmitatem adepto, pergit sanguis per arterias promoveri."

8. There are some animals, in which a circulation exists, although they are destitute of a heart. And in fishes, which have only a venous or pulmonary heart,

the arterialized blood is moved solely by vessels. The aorta is formed by the union of branches proceeding from the gills.

9. After the removal of the heart from a living animal, the blood may still be seen to flow in the small vessels. Mayo states, that in an experiment of Hall, a ligature was tied round all the vessels passing to and from the heart of a frog; yet the blood continued to flow with some rapidity into the arteries of the web of the foot; but after a few seconds it became slower, then stopped, when a retrograde rush of blood took place. After this, its ordinary flow was resumed, then a reflux again took place, and so on alternately, for a considerable time. Imperfect human fœtuses are sometimes destitute of a heart. In these the circulation must be carried on wholly by the action of the arteries and veins.

It may not be amiss to mention, in this place, a curious fact, which has sometimes been observed, in cases of amputation of the lower extremities, viz. that scarcely any blood has escaped from the incision of the soft parts; and, upon examination, it has been discovered that the main artery of the limb was ossified, or converted into a rigid tube of bone. If it were certain, in these cases, that the ossified artery was pervious throughout its whole extent, the fact would form a curious counterpart to that cited above, from Martini, viz. that in ossification of the heart, the blood still continues to circulate in the arteries. The true explanation of the phenomenon, however, we have probably yet to learn.

10. To the facts and considerations above mentioned, may be added the experiments of Hastings, which appear to establish, beyond a doubt, the irritability of the arterial canals. In these experiments the larger arteries of different animals, the aorta, femoral, and carotid, were laid bare, and subjected to different irritations, of a mechanical and chemical nature; and the result, in general, was increased contraction of the vessel operated upon.

When the vessel was scraped with the scalpel, the

irritation produced a contraction in it, or rendered its pulsations more perceptible, or occasioned an irregularity in the surface of the artery, which appeared to arise from a permanent contraction of the fibres of the middle coat. In some instances, a contraction was produced, which remained after the death of the animal. The application of ammonia produced similar effects, notwithstanding the assertion of Bichat, that no contraction can be produced in arteries by means of alkalies. In one experiment, an artery was proved by measurement to have shrunk one eighth in circumference, by the application of ammonia. In other experiments, it increased the action of these vessels; for, arteries which, when first exposed, scarcely pulsated, were very evidently contracted, and dilated immediately after being touched by the *liquor ammoniæ*. The nitric acid, also, occasioned a considerable contraction of the arteries.

11. The ganglionic nerves, distributed upon the coats of the arteries and veins, probably confer upon these vessels some vital endowment. In other organs, as the heart, the intestines and stomach, we find that this nervous influence is connected with a susceptibility to the influence of stimulants, and is, perhaps, the cause of it. One use of the nerves in the coats of the blood-vessels, perhaps, is to subject the blood to ganglionic innervation; another possibly may be, to render the vessels themselves excitable by the stimulus of the blood.

When an arterial trunk, the direction of which is straight, is exposed in a living animal, in general, no dilatation and no motion are perceptible to the eye, during the systole of the left ventricle. But on applying the finger to the vessel, the pulsation is readily perceived. According to Magendie, however, the dilatation of the aorta, during the systole of the heart, is manifest to the eye; and the same effect takes place in the divisions of the aorta of a certain magnitude; but the dilatation continually decreases in proportion as the arteries become smaller; and ceases wholly in those of a very small diameter. Mayo also asserts, that if an animal, in which the carotid artery

is exposed, be excited or alarmed, as by holding its nostrils for a few seconds, the heart will contract with violence, and the artery, instead of lying pulseless and motionless, will leap from its place at every systole of the left ventricle, becoming elongated, and assuming a tortuous appearance.

In the arteries which are curved, the pulsations are visible; because the impulse of the blood projected into them, tends to straighten or extend them, which produces a sensible motion in the vessels. The curvature of the aorta is the place, where this effect is most considerable.

Mayo states, that a partial dilatation of an artery may be produced, by exposing it in a living animal, and rubbing it for half a minute between the finger and thumb. A large artery in a living animal, as the carotid of an ass, or the crural artery of a dog, treated in this manner, becomes sensibly enlarged in the part subjected to the friction, assuming an ampullated appearance, which subsides in a quarter of an hour, if the wound be closed.

Functions of the Capillaries.—The irritability of the capillary vessels has been demonstrated, in the most conclusive manner, by the experiments of Dr. W. Philip. In some of these experiments, the blood was observed to move in the capillary vessels, after the excision of the heart, and even after death. The web of a frog's foot was placed in the field of a microscope, and the capillary vessels were distinctly observed to contract on the application of stimuli. The capillary vessels of the mesentery were observed to move the blood some time after the death of the animal. Dr. Philip also found, that the motion of the blood in the capillaries is influenced by the application of stimulants to certain parts of the nervous system, in the same manner as the motions of the heart, and wholly independently of any control exerted upon them by this organ.

There are reasons for believing, that the force of the heart and of the arteries is nearly exhausted, when the blood reaches the capillaries. The motion

of the blood gradually becomes slower, and the vital fluid ceases to move by jerks. Besides, the capillary vessels are the seats of the vital operations of nutrition, calorification, secretion, and hematosis; and it seems difficult to conceive that these processes, which are extremely variable in their activity, should not directly influence the quantity and the motion of the blood which supplies them with materials. In microscopic observations the blood has been observed to hesitate in its motion, to stop, as if uncertain what course to take, and even to move in a retrograde direction, with astonishing velocity and for a long time. If a part be irritated, the blood is seen to flow towards it suddenly in the capillary vessels, as if these exercised an attraction for it.

The portal circulation furnishes a strong argument in favor of the doctrine of the vital contractility of the capillaries. It is impossible to conceive that the power of the heart, can extend through two capillary systems, which the portal blood is obliged to traverse. The capillary vessels themselves must be the principal agents of this circulation.

It appears to be owing to the contractility of the capillaries surviving the other powers of the circulation, that the larger arteries in dead animals are found empty. In most cases the capillaries remain alive and active throughout the system, for a considerable time after respiration has ceased, working, as Dr. Arnott expresses it, like innumerable little pumps, drawing the blood out of the arteries, and forcing it into the veins.

The influence of the heart, however, is not annihilated in the capillary vessels, but extends through the capillary system into the veins. Magendie found, that when he compressed the femoral artery in an animal, the blood flowed out more slowly from the femoral vein; and as soon as the pressure was removed from the artery, again spirted out in a larger curve. When the action of the heart is feeble, the remote parts of the system are pale and cold. It appears, on the whole, that the blood moves in the capillaries under a three-

fold impulse, viz. the action of the heart, that of the arteries, and that of the capillaries themselves. This last is probably the chief cause.

But besides this impulse, to which the blood is subjected in the capillary vessels, and which impels it forwards in the course of the circulation, and causes it to pass from the arteries into the veins, it is subject to another, which attracts it into the parenchyma of the organs, to be employed in nutrition, secretion, &c. Between these two impulses the blood sometimes appears to hesitate, as if it were at a loss which to obey. The action of the heart moves it in the first direction; the peculiar action of the *nutrient* and *secretory* capillaries themselves draws it in the other. Any irritation applied to these vessels, increases the flow of blood towards them; a principle which is illustrated in inflammation. Hence, the attractive influence of the capillary vessels, regulates the quantity of blood which traverses the other parts of the circle of the circulation. They may either attract more or less blood to themselves, or refuse to receive it, and thus materially influence the course of the blood in the great vessels, change the pulse, and determine the quantity of blood which passes into the veins, and, consequently, of that which moves in the heart and arteries. The arteries and veins become larger in an organ which is the seat of a chronic irritation. From these, and many other similar facts, it appears not improbable, that the principal office of the heart is to propel the blood into the great arteries, which is thence drawn out, as it were, by the attractive power of the capillary vessels, determined by the wants of those parts of the system to which they belong.

When a part of the capillary system attracts to it more blood than usual, the fluxion extends to the neighboring vessels, and from them gradually to the larger arterial trunks. Hence the increased action of the arteries which go to an inflamed part.

Each organ attracts from the great vessels different quantities of blood, according to its degree of vitality, and the activity of its functions. Even in the same

part, the capillary circulation varies in its activity, according to the degree of excitement which happens to prevail. Every morbid condition of an organ is accompanied with a change in its capillary circulation. Further, there are some organs, whose functions are intermittent, as the uterus; and these must attract more blood into their vessels, when in a state of activity, than when at rest. All these considerations go to establish the importance of the functions of the capillary vessels, and appear to justify the opinion of Broussais, who considers the great vessels as a reservoir, to furnish the capillary system with blood; from which these last named vessels draw out only the quantity which they require.

It is difficult to determine the relative proportions of moving power, which the heart, arteries, and capillary vessels respectively contribute to the circulation. In general, the further we advance from the heart, the irritability of the arteries appears to increase; and in the capillary vessels it is so great, as to be sufficient to give motion to the blood, in some measure independently of the heart. The irritability of the arteries, then, is most inconsiderable nearest the heart, where, of course, it is least needed; but in the capillary vessels, where the action of the heart is but little felt, this deficiency is compensated by a high degree of irritability of the vessels.

Functions of the Veins.—The causes of the motion of the blood in the veins, also, have been a subject of much controversy among physiologists. These vessels possess little or no elasticity; for, though very dilatable, they appear to have little power of reaction upon their contents. They also appear to be endued with little, if any, irritability; and hence they seem to be incapable of contributing any contractile power, either physical or vital, to the circulation. It has, therefore, been supposed that the *vis a tergo*, derived from the heart, arteries and capillaries, continues to operate in propelling the blood in the veins, while these vessels are regarded as mere passive tubes. This opinion, however, is liable to strong objections.

The quantity of blood contained in the veins, appears to be too great to be sustained in the ascending branches, and kept in motion by the contractions of the heart and arteries, and the vital action of the capillaries, alone.

The veins are supposed to contain, at least, twice as much blood as the arteries; and a circumstance, which from the laws of hydrostatics, appears to be calculated to increase the pressure of this column of blood in the ascending veins, is, that the fluid is constantly passing into a narrower channel, in its ascent towards the heart. The contracting sides of the cone, along which the blood moves, oppose a resistance to the motion of the fluid, which a considerable part of the moving force is expended in overcoming. So that the *vis a tergo* has not only to sustain and propel twice the column of blood contained in the arteries, but, also, to overcome a degree of resistance arising from the structure of the venous tubes, the amount of which it is difficult to estimate.

But, setting aside this difficulty, and supposing that the *vis a tergo* were sufficient to propel the blood in the ascending veins, it is evident that these vessels would always be in a state of great distension. In the lower extremities, especially, they would have to sustain such a degree of lateral pressure, as would keep their coats constantly on the stretch. Yet we do not find that this is the actual condition of the veins of the feet and legs. They never become so much distended, as to be converted into rigid tubes; which, however, would necessarily be the case with these vessels, if the blood moving in them were propelled solely by a force from behind. For, so long as the veins yielded to the pressure of the blood, this fluid, instead of rising in these vessels, would be accumulating in, and distending them; and not until their sides were distended to the utmost, would the propulsive power behind be enabled to force the blood upwards.

Another force, which has been considered as one of the moving powers of the venous blood, is the contraction of muscles in contact with the veins, or through

which these vessels pass. This has been inferred from the quickened circulation, and the strong pulsations of the heart and arteries, which follow great muscular exertions. The muscles, during their contraction swell and press upon the veins in contact with them and force the blood from the parts immediately subjected to their pressure. The blood, then, has a tendency to move in all directions from the centre of pressure, but is prevented from flowing in a retrograde direction, by the valves with which the vessels are provided; and, of course, is necessarily directed towards the heart. When the muscle is relaxed, the vein is relieved from the pressure, and receives a new supply of blood from the capillaries. It is evident, however, that muscular contraction must be a secondary, and by no means a principal agent; for there are certain diseases, as fever, in which the muscles are perfectly at rest, and yet the circulation, and, of course, the motion of the venous blood, is as impetuous, as after violent exercise. And, besides, it appears extremely improbable that nature would have relied, for the continuance of a function, which cannot be suspended for a moment without destruction, upon an agent so precarious and uncertain, as the action of the voluntary muscles.*

Muscular action seems to be most necessary, to promote the flow of the venous blood in those parts of the system, where the veins are destitute of valves, as in the abdomen. Hence a congestion of venous blood in the portal system, engorgement of the liver, and enlargements of the hemorrhoidal vessels, are the natural consequences of inactive and sedentary habits of life.

The veins themselves, also, exert a motive action upon the blood. This action is different from that of the heart, but is not simple elasticity; for, if a vein be punctured between two ligatures, the blood spirts out with greater force during life, than after death. Indeed it is said, that true irritability exists in the great venous trunks, as the vena cava inferior, especially in

* Carson.

cold-blooded animals. Every one has noticed the shrinking of the external veins; as, of those in the back of the hand, in cold weather. They contract, perhaps, to one third of their ordinary diameter.

Hastings found, that both the capillary veins and the large venous trunks, readily and sometimes violently contracted, on the application of certain stimuli. The oil of turpentine, applied to small veins, occasioned a great contraction of their diameters. The nitric acid produced so strong a contraction, in veins irritated by it, that the passage of the blood was almost wholly prevented. On applying nitric acid to a trunk of one of the pulmonary veins in the thorax of a cat, the vessel, with all its branches, became much contracted. A similar effect was produced in the abdominal cava of a cat, by the application of nitrous acid. When the experiment was performed after death, the vessels became white from the contact of the acid, but suffered no contraction of their coats. These facts demonstrate a vital power of contraction in the veins, from which it may be inferred, that they are not mere passive tubes in the function of the circulation. In some situations, however, the veins cannot contract upon the blood, from their connections with the neighboring parts. This is the case with the veins of the liver, and those which pass through the substance of bones. The sinuses of the dura mater are in the same predicament.

Another power, which some physiologists have supposed to assist in giving motion to the venous blood, is the active dilatation of the heart, by which it is conceived the blood is sucked up in the veins, like water in a pump. On opening the thorax of a living animal, and applying the finger to the heart, it will be perceived that the dilatation of the organ is an active operation, and not a mere relaxation of its muscular fibres. So, where the heart of a frog is cut out, and put into warm water, it will continue to contract and dilate with great energy, throwing jets of the fluid to some distance. Another fact, which is favorable to the same opinion, is, that after death, the ventricles are

generally found distended with blood, from which it seems to follow, that the state of dilatation is the natural condition of the organ.

Dr. Bostock regards the dilatation of the heart as the effect of the elasticity of the organ, overcome at first by its irritability, which from the contact of the blood, causes it to contract to a smaller volume, than that at which its elasticity would maintain it; but, after the stimulating cause is removed by the contraction of the ventricle, the elasticity being no longer counteracted, is left at liberty to exert itself, and restores the heart to its former volume.

The suction power of the heart, however, is not admitted by all physiologists. Dr. Arnott denies it, and asserts, that, even admitting it to exist, it could not promote the motion of the blood in the veins, because these vessels, being pliant, flexible tubes, would collapse by the atmospheric pressure, instead of suffering the blood to be pumped up in them, by the suction of the heart. If the point of a syringe be inserted into a piece of intestine or eel skin, or a vein filled with water, on attempting to pump up the water, by drawing the piston of the syringe, the water nearest the mouth of the syringe, Arnott observes, will be drawn in, and then the sides of the tube will collapse, acting as a valve to the mouth of the instrument, and putting a stop to the experiment. This experiment of Arnott's, however, is not a fair representation of the actual condition of the veins in the living body. For while the circulation is going on, the capillary vessels are constantly forcing blood *into* the veins, as fast as it is flowing *out* of them by other causes. The experiment, in order to be satisfactory, ought to be performed in a different manner. Into a piece of intestine, or eel-skin, filled with water, should be inserted, not only one syringe, to draw the water *out*, but another, at the opposite extremity, to force it *in*, in the same proportion, so as to keep the vessel constantly full. Then the atmospheric pressure could not make the tube collapse, but would be exerted upon the column of fluid contained in it, and force it into the upper syringe.

The expansion of the thorax during inspiration, is another force, which promotes the flow of venous blood towards the heart. Inspiration establishes a kind of focus of suction in the chest, by which both air and blood are drawn into it. When the chest is dilated by inspiration, the jugular veins are observed to empty themselves and collapse; but during expiration they rise, and become turgid with blood. Magendie introduced a gum elastic tube into the jugular vein of a living animal, so as to penetrate into the vena cava, and even into the right auricle, and the blood was observed to flow from the open extremity of the tube, only at the time of expiration. During inspiration, the suction power drew the blood into the chest, and prevented its rising in the tube. Barry inserted one end of a spiral tube into the jugular vein, and plunged the other into a vessel filled with colored fluid. During inspiration, the fluid was drawn from the vessel *into* the vein, but, at the time of expiration, it remained stationary in the tube, or was repelled into the vessel.

On the whole, the effect of inspiration is to promote the flow of blood towards the chest, and, of course, to empty the remote parts of the circulating system; while expiration produces the opposite effect, obstructing the flow of blood to the chest, and engorging the periphery of the circulation.

It must be considered, however, in reference to the influence of the expansion of the chest upon the circulation, that there is only one act of respiration, for every five or six pulsations of the heart; and, consequently, that the blood passes five or six times into the auricles of the heart, while respiration takes place but once. In the fetal state, respiration does not exist, yet the circulation has a much greater velocity than after birth.

It appears, on the whole, that a variety of causes concur, in giving motion to the venous blood, viz. the *vis a tergo* derived from the action of the heart, the arteries, and the capillary vessels; the contractile power of the veins themselves; the aspiratory action

of the heart; the expansion of the lungs in inspiration; and the contraction of the muscles in contact with the veins.

Some of the German physiologists assume a self-moving power in the blood, by virtue of which it exerts an effort to diffuse itself throughout the body. They assert, that the blood seeks out or makes new passages for itself in the organs. So in the incubated egg, globules of blood, it is said, may be seen moving in currents, before the vessels are formed.

Influence of the Nervous System upon the Heart.

The heart is more independent of the great nervous centres, particularly of the brain, than many other organs. Acephalous fetuses frequently live until birth, and sometimes a few days longer. Reptiles have lived six months without a head; and mammiferous animals may live some time after the loss of the head, if the vessels of the neck be tied to prevent death by hemorrhage, and respiration be maintained artificially.

The principle of the heart's action appears to reside in the organ itself, though some physiologists suppose it to be derived from the nerves distributed throughout its substance, derived from the ganglionic system and the *par vagum;* and the innervation of the cerebro-spinal axis, particularly of the dorsal part, is supposed to be necessary to the motions of the heart, in their perfect developement.

The influence of the nervous system upon the circulation is established by many facts. After a considerable injury to any part of this system, as the spinal cord, the brain or the nerves themselves, the circulation of the blood is enfeebled or partially destroyed, in the part, whose nerves have been isolated from the rest of the nervous system. For example; if the sciatic nerve be divided, the circulation becomes feebler by degrees, and at length wholly ceases in the lower extremity of the same side; but remains unimpaired, or nearly so, in the other parts of the body. The heart's action is impaired by the division of the prin-

cipal nerves, proceeding from the spinal marrow, and the more so as more of these nerves are divided. Very severe injuries of the brain, or spinal cord, sometimes occasion a total cessation of the circulation. The influence of the nervous system upon the living blood itself, transmitted by the coats of the blood-vessels, is supposed by some physiologists to be sufficient to maintain the circulation of the blood in particular parts, without the aid of the heart.

But, it should seem, from facts mentioned by Brachet, that the great sympathetic exerts the greatest nervous influence over the heart. This writer cites from Hufeland's journal, some experiments of Bartels, on persons who had been beheaded. Six highway robbers had lost their heads near Marbourg, and on opening the bodies of the whole six, a few minutes after their execution, the heart was observed to contract and dilate alternately, with considerable force, and in a regular manner. The motions, however, gradually diminished in strength, for the space of half an hour, but were instantly re-excited, by irritating a filament of the great sympathetic; while the irritation of the spinal marrow, merely gave rise to contractions of the muscles of the trunk, without producing any effect whatever upon the heart.

The influence of the sympathetic upon the action of the heart, was demonstrated, in a very conclusive manner, by experiments on dogs, performed by Brachet himself. In these experiments Brachet succeeded, after many failures, in isolating, on each side, the inferior cervical ganglions, and, upon dividing all the filaments which proceeded from them, he found that the action of the heart, after a few irregular contractions, was almost immediately annihilated, and the circulation ceased.

In another experiment, he exposed the cardiac nerves, and followed them into the chest, until he reached the cardiac plexus. Having succeeded in isolating this body, he divided it with a pair of scissors; upon which, the circulation instantly stopped, the heart ceased to contract, and the animal became

rigid, and expired. From these experiments, Brachet inferred, that the heart derives its principle of motion from the ganglionic system.

CHAPTER XV.

Respiration.

The third and last of the vital functions, is respiration, a function which is indispensable to animal, and even vegetable existence. By respiration, the assimilation of aliments, which commenced in the stomach and intestines, is finally completed in the lungs, by their conversion into blood; and this fluid itself, after being drained of its nutritive and vivifying principles, in administering to the various operations of life, is again reanimated by the influence of atmospheric air, and prepared anew to dispense life and nutrition throughout the system.

In the human species, and the higher classes of animals, respiration is accomplished by certain organs, called the lungs; two viscera, which fill the cavity of the thorax, of a spongy texture, extremely vascular, and divided into lobes. The two lungs are separated from each other, by the *mediastinum* and the heart, and are enveloped by membranes, termed the *pleuræ*. Their figure corresponds with that of the cavity of the thorax, with the walls of which they are always in contact, so that no air can intervene between them. In consequence of their tissue, after birth, being always penetrated with a great quantity of air, their specific gravity is less than that of water, and they swim when placed in this fluid.

The substance of the lungs is composed of innumer-

able fine cells, connected together by a delicate cellular membrane. Each lung is divided by deep fissures into sections, termed lobes, of which the right lung contains three, the left only two. Each of these lobes is subdivided into smaller lobes, or lobules, and these, again, into the fine cells above mentioned. Each lobule is surrounded by a thin layer of cellular tissue, which separates it from the adjoining lobules. Each lung is attached to the spine by its root, where blood-vessels, nerves, lymphatics, and a branch of the windpipe enter it. The lungs are covered by a transparent membrane, termed the pleura, which is reflected from the root of the lungs, over the spine and sternum, ribs, intercostal muscles, and diaphragm.

Air is admitted into the lungs, by means of the trachea or windpipe, a tube eight or ten inches long, composed of cartilaginous arches, or imperfect rings, deficient on the posterior side; of cellular and muscular coats, and a lining of mucous membrane.* The canal is completed behind by a fibrous membrane. The trachea is situated before the vertebral column, in the posterior mediastinum, resting on the œsophagus, and extending from the lower parts of the larynx to the level of the second or third dorsal vertebra. Here it bifurcates, or divides into two branches, termed *bronchia*, one of which passes to the right lung, and the other to the left.

Each of the bronchia subdivides, as it enters the lung; the right, into three branches, which are severally distributed to the three lobes of the right lung; the left into two, corresponding with the two lobes of the left lung. As they penetrate into the lungs, they subdivide more and more, branching throughout the whole pulmonary tissue, until their extreme divisions terminate in the fine vesicles, which constitute the principal part of the substance of the lungs. Each

* It is a curious fact, that birds can live several hours with the trachea tied, provided one of the hollow bones, into which the air penetrates in respiration, be sawed open so as to admit the air. But if a vessel containing carbonic acid, or azote, be adapted to such an opening, the bird soon dies.

ramification of the bronchia is connected with a particular cluster of these cells, and if air be forced gently into it, it will inflate this, but none of the neighboring cells, unless the force employed be so great as to rupture the sides of the cells. The air cells are said to be about the one-hundredth of an inch in diameter.

The trachea and bronchia are lined by a mucous membrane, which is a continuation of the membrane of the larynx, and extends to the termination of the bronchia. It is lubricated with mucus, secreted by mucous follicles interspersed throughout it. The outer membrane of the tracheo-bronchial tube consists of longitudinal and parallel fibres, and is considered by some as analogous to the muscular tunic of the intestines, but by Beclard, as identical with the yellow tissue of the arteries. This membrane connects together the cartilages of the trachea posteriorly, filling up the deficiency of the cartilaginous rings, and completing the formation of the tracheal tube.

In the smaller divisions of the bronchia, the cartilaginous arches wholly disappear, and the fine aërial canals consist merely of the fibrous and the mucous membranes.

The lungs are supplied with two distinct circulations, one of which is destined to the nutrition of the organs, the other is connected with their peculiar functions, viz. respiration, or hematosis. They receive, first, arteries which spring from the aorta, and convey arterial blood for the nutrition of the lungs, ramifying over the bronchia, and termed the *bronchial* arteries; and, secondly, the *pulmonary* artery, a large vessel which arises from the right ventricle of the heart, and conveys venous blood to the pulmonary capillary system, in order to be converted into arterial blood by respiration.

These organs also possess two capillary systems; viz. one, which is a part of the *general* capillary system, is the seat of the nutrition of the lungs, and of the transformation of arterial into venous blood, and intermediate between the bronchial arteries and veins; the other, or the *pulmonary* capillary system, is the

seat of the peculiar functions of the lungs, or of the conversion of venous into arterial blood. This is intermediate, between the pulmonary artery and the pulmonary veins.

The lungs are abundantly supplied with lymphatics and conglobate glands. The latter are situated at the bifurcation of the trachea, around the bronchia, and some of them are found in the interior of the lungs. The nerves of these organs are derived from the pulmonary plexus, formed by branches of the pneumo-gastric, and the great sympathetic.

The thorax, or chest, in which the lungs are situated, is a box of bones, formed anteriorly by the sternum, laterally by the ribs, of which there are twelve on each side; and posteriorly by the dorsal vertebræ. The seven superior ribs are termed true ribs, the five lower ones, false. The true ribs are attached posteriorly to the vertebræ, by moveable articulations, and anteriorly with the sternum, by cartilaginous prolongations. The ribs are connected together by two strata of muscles, which are termed intercostal. Below, the thorax is bounded by the midriff, or diaphragm, which separates it from the cavity of the abdomen. This muscular partition, though dividing the trunk of the body transversely, does not form a horizontal plane, but arches upwards into the thorax, forming a considerable concavity, when viewed from the abdomen.

All the parts of the thorax are moveable, and are so arranged, that its cavity may be enlarged in every direction. It may be enlarged vertically, by the contraction of the diaphragm; for, in contracting, this muscle loses in some measure its arched form, and becomes depressed and flattened towards the abdomen, so as to diminish this cavity, and enlarge, in the same measure, that of the thorax. Laterally, the thorax may be enlarged by the elevation and abduction of the ribs, the arches of which are drawn upwards and outwards, by the contraction of the intercostal muscles; and, in the antero-posterior direction, its cavity may be increased, by the elevation of the sternum.

There are several muscles, employed in giving motion to the walls of the thorax. These are, besides the diaphragm and intercostal muscles, the *serrati*, the *scaleni*, the *subclavius*, the *levatores costarum*, the pectoral muscles, the abdominal muscles, &c.

The phenomena of respiration may be divided into three classes, *mechanical*, *chemical*, and *vital*. The *mechanical* phenomena comprehend the mechanism, by which air is alternately drawn into and forced out of the lungs; the *chemical* relate to the changes, which the air undergoes in the lungs; and the *vital*, to those which are effected in the blood, by the contact of the air.

Mechanical part of Respiration.

The mechanism of respiration may be reduced to the two phenomena of *inspiration* and *expiration*, or the alternate introduction of air into the lungs, and its expulsion from these organs.

Inspiration, or the introduction of air into the lungs, is effected by the dilatation of the thorax, which is accomplished by the depression of the diaphragm, and the elevation and abduction of the ribs and sternum. By these motions, the cavity of the chest is enlarged in its three principal diameters, vertical, lateral, and antero-posterior. The vertical diameter, extending from the centre of the diaphragm to the top of the chest, is seven or eight inches in length, and this is increased by the contraction of the diaphragm, from two to four inches, according to the depth of the inspiration. It is chiefly the lateral parts of this muscle, which become depressed in inspiration, its centre being tendinous and incapable of contraction, and besides, being fixed by its attachment to the sternum and to the pericardium.

The lateral, or transverse diameter, is nine or ten inches in length, and is increased, by the ascent of the ribs, to eleven or twelve. The arches of the ribs are drawn outwards as well as upwards, during their elevation; an effect which is owing to the obliquity of the planes which pass through their arches, in relation to

the spinal column, with which they are articulated. From the same cause, the sternal extremities of the ribs advance forwards in their ascent, carrying the sternum with them, and thus increasing the depth of the chest from before, backwards. This diameter is five or six inches in length, and may be increased by the elevation of the ribs, from an inch to an inch and a half.

The elevation of the ribs is accomplished, in ordinary inspiration, by the contraction of the intercostal muscles. The first rib is made a fixed point, by the action of the scaleni and subclavian muscles, and all the others are raised towards the first, by a general and simultaneous movement, caused by the action of the intercostal muscles.

In difficult or excited respiration, several other muscles contribute their aid, in elevating the ribs; as the *great serrati*, the *superior serrati postici*, the *pectoral* muscles, the *latissimus dorsi*, the *sterno-cleido-mastoid*, &c.

According to Magendie, there are well-marked degrees of inspiration, viz. 1. *ordinary* inspiration, which is effected by the depression of the diaphragm, and a very gentle and scarcely perceptible elevation of the thorax; 2. *full* inspiration, in which there is a very evident elevation of the thorax, as well as depression of the diaphragm; and, 3. *forced* inspiration, in which the dimensions of the chest are enlarged to the utmost, in every direction. In the first, or ordinary degree of inspiration, the air penetrates only a part of the pulmonary tissue; in the second, it inflates a larger portion of the lungs; but it is only in the third, that the whole extent of these organs is pervaded by it. In the third degree of inspiration, several muscles are employed, which are attached by one of their extremities to the arms; in consequence of which, it becomes necessary that the arms be previously fixed, or made a point of support for these muscles to act upon. Hence, in violent dyspnœa, from asthma, or any other cause, the sufferer instinctively seizes the arms of his chair, or any other solid body, in his efforts to elevate the

ribs and expand the thorax. In making violent efforts, on the contrary, as in raising heavy burdens, in pushing, &c. in evacuating the bladder, or the rectum, and in the efforts of parturition, *the walls of the thorax* are made a fixed point for the muscles of the arms or abdomen, by taking a deep inspiration, and then closing the glottis, to prevent the escape of the air from the lungs. If the muscles which close the glottis be paralyzed, by dividing the laryngeal nerve, or the glottis be kept open by the introduction of a canula, a strong effort becomes impracticable.

The condition of the lungs in the thorax has been compared to that of a bladder, enclosed in a receptacle, having moveable walls, in such a manner that no air can penetrate between the two, and that the mouth of the bladder opens to the external air. In these circumstances, if the walls of the receptacle be separated farther from each, the effect will be to remove the pressure of the atmosphere from the external surface of the bladder, while its internal surface will remain exposed to it, by means of its mouth, which opens externally. The weight of the atmosphere, thus acting upon the internal surface of the bladder, and not being counteracted by any external pressure, will keep this membranous sac in close apposition with the walls of the receptacle, and oblige it to follow all the motions of the latter.

The situation of the lungs enclosed in the thorax, is very similar; and, consequently, when the chest is expanded by the action of the inspiratory muscles, all pressure is removed from the external surface of the lungs, the air contained in these organs expands by its elasticity, and keeps their external surface in close contact with the walls of the chest; and a volume of air, at the same time, rushes through the glottis and windpipe into the lungs, sufficient to restore the equilibrium between the rarified air contained in these organs, and the external atmosphere.

The first act of inspiration, after birth, may be accounted for in the same manner. The inspiratory muscles of the new-born infant are excited to action,

either by the irritation of the external air, or by an instinctive feeling then first developed; the chest is expanded, air rushes in through the windpipe and unfolds the lungs, and respiration commences.

Expiration, or the contraction of the thorax, which succeeds inspiration, is the result of several forces. These are of two kinds, *passive* and *active*. The passive are the weight of the ribs and parietes of the chest; the resilience, or elastic reaction of the sterno-costal cartilages, which had been put on the stretch, and subjected to a degree of torsion in inspiration; and the elasticity of the bronchial tubes. The active powers are the abdominal muscles, which force the viscera against the diaphragm, and thus diminish the vertical diameter of the chest. Another effect of the action of the abdominal muscles, is to fix the inferior ribs, so as to make them a point of support, towards which the superior may be drawn by the intercostal muscles, which may thus be rendered instruments of expiration. The *sacro-lumbalis*, the *longissimus dorsi*, the *serrati postici inferiores*, the *quadratus lumborum*, the *triangularis sterni*, contribute to the same effect, that of depressing the inferior ribs, and diminishing the transverse and antero-posterior diameters of the thorax.

According to Magendie, expiration, like inspiration, presents three degrees, viz. 1. *ordinary;* 2. *large;* and, 3. *forced* expiration.

In the first degree, or *ordinary* expiration, there is a diminution of the vertical diameter, produced by the relaxation and ascent of the diaphragm into the thorax; this muscle being pushed up by the abdominal viscera, which are compressed by the anterior muscles of the abdomen. The second degree, or *large* expiration, is the effect of the relaxation of the muscles which elevate the chest, permitting the ribs and sternum to sink down by their own weight, and to resume their ordinary relative situation, in respect to the vertebral column. *Forced* expiration is the result of a powerful contraction of the abdominal and the other expiratory muscles, pushing the diaphragm up

into the chest, and producing the utmost possible depression of the ribs.

The oblique and transverse muscles of the abdomen, however, which are considered as the antagonists of the diaphragm, and the principal agents of ordinary expiration, are not essential to this function, and perhaps have less concern in it, than has been generally supposed. If the ribs were drawn down by the contraction of these muscles, we should expect that they would feel tense and rigid during expiration, which is not the fact. Besides, in extensive wounds of the abdomen, where the bowels are protruded, respiration could not be carried on, if expiration were effected by, or required, the pressure of the abdominal viscera against the diaphragm; for, in these cases, the intestines, instead of being pressed up against the diaphragm, are always protruded through the wound; and, what is worthy of notice, this protrusion takes place *during inspiration;* a fact, which proves, that it is at this time, that the intestines suffer the greatest pressure, and not during expiration, when they are supposed to be so strongly compressed by the action of the abdominal muscles. To these considerations, it may be added, that, in certain experiments, these muscles have been divided transversely, or even altogether removed, and yet respiration has continued for a considerable time.*

Carson considers the elasticity of the lungs as an important agent in expiration. The lungs have a strong tendency to collapse, and they are prevented from obeying this tendency, only by the pressure of the air within them. But if an opening be made into the cavity of the chest, so as to expose the external surface of the lungs to the atmosphere, and thus equalize the pressure on their external and internal surfaces, then the lungs are left at liberty to exert their collapsing power, and to assume the dimensions which their structure and their elasticity make natural to them. Hence, wounds penetrating into the thorax,

* Carson.

are followed by a collapse of the lungs, and cessation of respiration on the injured side of the chest. Carson found, by experiments on calves, sheep, and dogs, that the collapsing effort of the lungs was equal to the pressure of a column of water, from a foot to a foot and a half in height. It should seem from this, that the lungs are in a forced state of expansion during life, and that they have a constant tendency to collapse, and to recede from the walls of the thorax. When the inspiratory muscles cease to act, and to maintain the chest in a state of dilatation, the collapsing power of the lungs may be exerted with effect, to a certain extent; because, then, there is nothing to prevent it. The lungs then shrink to their former volume, forcing out the air which had been admitted by the preceding act of inspiration; and, as the lungs shrink, the diaphragm and intercostals, now passive, offer no resistance to the external air which presses upon the walls of the thorax, keeping them in contact with the collapsing lungs, so as to prevent the formation of a vacuum in the chest.

According to Rudolphi, the larynx, trachea, and lungs themselves, take an active part in respiration. The larynx, he remarks, is in incessant motion, in the act of breathing. In inspiration, the arytenoid cartilages are drawn apart by the muscles, who go to them from the thyroid and cricoid cartilages, and the glottis is thus opened. In expiration, on the contrary, the arytenoid cartilages are drawn towards each other again by their own proper muscles, and the glottis is thus closed. In birds, and the amphibia, which are destitute of an epiglottis, these motions, according to Rudolphi, may easily be seen, by drawing the tongue forward, or bending back the lower jaw.

With the larynx, the trachea, with all its branches, or the lungs themselves, are in simultaneous action.—While the arytenoid cartilages are separated from each other, in inspiration, the inner, or longitudinal fibres, which run the whole length of the trachea, and its ramifications, contract, by which means all these parts are raised and dilated, so as to offer an

easy admission to the air. These fibres afterwards become relaxed, and the air passages are contracted—an effect to which the transverse muscles of the trachea contributes; and the air is thus expelled.

According to this view, all these parts are active in respiration, and of course the comparison of the lungs to a bladder, which is partially expanded and contracted by the ingress and egress of air, is wholly unsuitable. The fibres of the lungs, according to Rudolphi, can even act, when these organs have grown to the side, and externally are wholly immoveable.

These are some of the principal facts relating to the physical or mechanical part of respiration.

Chemical phenomena of Respiration.

The *chemical* phenomena, relate to the changes, which the air received into the lungs, undergoes in respiration.

The atmosphere is that invisible, elastic fluid, which surrounds the earth to the height of about forty miles, and which is absolutely necessary to the existence of all organized living beings, vegetable as well as animal. Its specific gravity, compared to that of water, is as 1 to 770. A column of it, extending to the top of the atmosphere, is equal in weight to a column of water of the same diameter, thirty-two feet, or to a column of mercury twenty-eight inches in height. The pressure which it exerts upon the human body, is consequently enormous, amounting to between thirty and forty thousand pounds on a middle-sized adult.

Atmospheric air is composed essentially of three elements, viz. oxygen, azote and carbonic acid—in the proportion of 20 or 21 per cent. of oxygen, 78 or 79 of azote, and 1 or 2 of carbonic acid.

Oxygen is an invisible aëriform body, rather heavier than atmospheric air, possessing a strong tendency to combine with many other substances in nature, and forming with them certain compounds, called acids, and oxyds; it enters into the composi-

tive of air, water, and of all vegetable and animal substances; is the principal supporter of combustion, and is an element essential to the formation and renovation of the blood, both in aërial and aquatic animals.

Azote is an invisible, gaseous body, lighter than oxygen and atmospheric air, and incapable of supporting combustion. In most animals, it is incapable of supporting respiration, though according to Vanquelin, it is the element which supports it in several of the inferior classes of animals. It is one of the essential elements of animal matter, and exists in some families of plants. Experiments seem to have proved, that it is both absorbed and exhaled in respiration.

Carbonic acid, also, is an invisible aëriform substance, of a slightly acid taste, of a greater specific gravity than azote or oxygen, capable of forming salts by combining with salifiable oxyds, irrespirable by animals, and extinguishing burning bodies. Though it occasions asphyxia in animals who inhale it, it seems to be essential to the respiration of plants. It is always present in atmospheric air, though in a very minute proportion.

Atmospheric air contains, also, the imponderable elements, light, heat, and electricity; more or less of watery vapor; exhalations from plants and animals; and many other accidental admixtures.

The presence of the essential, as well as the accidental ingredients of the atmosphere, may be determined without difficulty. The presence of oxygen is ascertained by the combustion of a lighted taper in air; that of carbonic acid by its making lime water turbid; and that of azote, by the formation of ammonia with hydrogen, in the conditions requisite to the combination of the two elements. Caloric and light become sensible, by subjecting the air to sudden compression in a glass condenser—water by the moisture deposited by a mass of air, when suddenly cooled, &c.

Such is the composition of atmospheric air, which is so indispensable to respiration, and consequently to the support of animal life.

Upon analyzing a portion of air, which issues from the lungs in expiration, it is found, that the proportion of its elements has undergone a considerable change; and this change is found to consist in an increase of the carbonic acid, a diminution of the oxygen, and the addition of a large quantity of watery vapor, containing some animal matter in solution. Thus, instead of consisting of twenty or twenty-one parts of oxygen, seventy-eight of azote, and one or two of carbonic acid, like atmospheric air, the air of expiration contains only about fourteen per cent. of oxygen; its carbonic acid is increased to about eight per cent.; while the proportion of its azote remains nearly unaltered. It appears, then, that the portion of air which has been employed in respiration, loses about seven per cent. of oxygen, and acquires about an equal quantity of carbonic acid, while the quantity of its azote undergoes little or no change.* Now, if it be admitted that the volume of carbonic acid, which is formed in respiration, is exactly equal to that of the oxygen, which has disappeared, it suggests a very simple theory of the changes which the air undergoes in respiration. As carbonic acid is formed by a combination of carbon and oxygen, and as a certain volume of oxygen gas disappears in respiration, and its place is supplied by an equal volume of carbonic acid, it seems natural to infer, that the air introduced into the lungs has furnished the oxygen, and the blood in the lungs, the carbon, of which this carbonic acid is composed. According to this view, the whole of the oxygen, which has disappeared, is still present in the air of respiration, but it exists in a state of chemical union with carbon, under the form of carbonic acid.

It has been ascertained, however, by the researches of Lavoisier, and Seguin, of Davy, and more recently

* It appears to be owing to the increased proportion of carbonic acid, rather than to the loss of oxygen, that air, which has been respired, loses its fitness for respiration. According to Le Pelletier, it appears from experiments, that an air composed of forty per cent. oxygen, forty-five of azote, and fifteen of carbonic acid, will not effect hematosis, though it contains twice the proportion of oxygen, which exists in common air.

by those of Dr. Edwards, that a quantity of oxygen disappears in respiration, which exceeds what is necessary for the formation of the carbonic acid which is generated. Edwards estimates this excess of oxygen consumed in respiration, above the volume of carbonic acid formed, when at its maximum, at nearly one third of the oxygen which has disappeared, and as varying from this, almost down to nothing. The variation of this excess depends on a variety of circumstances, as the age, the species, or the peculiar constitution of the animal employed in the experiment.

Now, if it be true, that more oxygen is consumed in respiration, than can be accounted for by the carbonic acid which is formed and is present in the air of respiration, it must be supposed that a part of the oxygen, at least, which has disappeared, has been absorbed by the lungs, while the remaining part may be supposed to have combined with the carbon of the blood, to form carbonic acid. But if a part of the oxygen is actually absorbed by the lungs, some physiologists have been disposed to believe that the whole of it is, and that the carbonic acid expired is not formed by an union of oxygen and carbon in the lungs, but is secreted and ready formed from the blood. This opinion is adopted by Dr. Edwards, and is corroborated by some of his experiments. He found that if frogs, in the month of March, were confined for eight hours in pure hydrogen gas, after their lungs were exhausted of air by pressure, they continued to breathe, though less and less vigorously, and expired a volume of carbonic acid gas, nearly equal to their own bulk.* Similar results were obtained in experiments upon kittens. A kitten three or four days old, was placed in a receiver filled with pure hydrogen gas, and in nineteen minutes, performed about an equal number of inspirations. Upon afterwards examining the air contained in the re-

* Rudolphi, however, is of opinion, that the carbonic acid, produced by a frog contained in a globe of hydrogen gas, is not exhaled from the lungs, but from the skin.

ceiver, it was found to contain twelve times as much carbonic acid as could be accounted for by the air contained in the lungs of the animal at the beginning of the experiment.

Edwards's experiments also proved that nitrogen is sometimes absorbed in respiration, or, at least, that a variable proportion of this principle disappears in this process; a fact, which had been previously asserted by Cuvier and Davy. Edwards found, also, that when small birds were immersed in a large quantity of air for a limited time, there was, in many instances, an evident increase in the quantity of nitrogen, while, in others, there was a loss of this principle. He observed, that these different results had some connection with the season of the year, when the experiments were performed. In winter, a deficiency of azote was observed in the air respired, but in spring and summer, the quantity of this principle was found to be increased. Edwards inferred from his experiments, that both absorption and exhalation of azote are constantly going on in the lungs during respiration, and that, according to the predominance of one or the other of these processes, or their exact equality, there is a deficiency or excess of azote in the air expired, or the volume of this principle remains unaltered.

The quantity of air received into the lungs in inspiration is exceedingly variable, and has been very differently estimated by different physiologists. Gregory estimated it at only two cubic inches. According to Rudolphi, the naturalist Abildgaard states of himself, that with a small chest he inspired, in ordinary respiration, three cubic inches of atmospheric air; but about every sixth or seventh inspiration, his breathing was deeper, and he inspired from six to seven, and sometimes even fifteen cubic inches. Herthold, with a more capacious chest, inhaled, in every act of respiration, from twenty to twenty-nine cubic inches; while Keutch, inspired only from six to twelve. Goodwyn estimates the volume of air inspired at about 14 cubic inches; Davy, at from 13 to

17—Cuvier at 16; Allen, and Pepys at 16½; Menzies at 43.77. It is estimated, by late observers, that the greatest quantity of air, which can be drawn into the lungs in forced inspiration, is about seventy cubic inches. It is not probable, that the air inspired reaches at once the ultimate ramification of the bronchia. The air-cells are constantly filled with a certain quantity of air, left by preceding inspirations. It is probable that the air last inspired, is mixed by degrees with the residual air present in the cells, and that it serves to keep this in a fit state to arterialize the blood. The quantity of air contained in the lungs after an ordinary or a forced *inspiration*, and after an ordinary or a forced *expiration*, has been differently estimated. According to Berthold, the lungs of an adult, after a forced inspiration, contain about two hundred and fourteen cubic inches of air; after a common inspiration, one hundred and twenty cubic inches; after a common expiration, one hundred and six cubic inches; and after a forced expiration, only eighty-five.

Menzies says, that many men are able, after ordinary expiration, to expel seventy cubic inches more from their lungs. He thinks from this, that the lungs can hold two hundred and nineteen cubic inches, and, after a common expiration, still contain one hundred and seventy-nine cubic inches.

Allen and Pepys estimate the quantity of air, contained in the lungs after an ordinary expiration, at only one hundred and three cubic inches. They state, as the results of their experiments, that the lungs of a man of common size, contain, after death, more than one hundred cubic inches of air. Rudolphi thinks, that Allen and Pepys's estimate of the volume of the air respired, may be admitted as correct, in ordinary respiration; and in women and children, that it may be lowered. But between the ordinary acts of respiration he observes, there occur, from time to time, fuller inspirations and expirations; and in healthy laboring men, with capacious chests, he thinks Menzies' estimate not too high.

In four subjects, who died natural deaths, and of course *after expiration*, Goodwyn found that the lungs contained severally one hundred and twenty; one hundred and two; ninety; one hundred and twenty-five cubic inches of air. The average of these is one hundred and nine.

In the lungs of hanged persons, who *inspire deeply* before death, he found, in one case, two hundred and seventy-two; in another two hundred and fifty; and in a third, two hundred and sixty-two cubic inches of air.

It is said that we can expel one hundred and seventy cubic inches of air by forced expiration, and that one hundred and twenty cubic inches will still remain in the lungs. If this be true, the volume of air, which these organs contain in their quiescent state, must be the sum of these two quantities, or two hundred and ninety cubic inches.

Now, if it be assumed, that we inhale forty cubic inches in inspiration, the whole volume of air, which the lungs contain in a distended state, is three hundred and thirty cubic inches, and consequently only one eighth of the contents of the lungs, is changed by every act of respiration. But, if we inhale only about fifteen cubic inches in ordinary respiration, which is probably near the truth, the quantity of air contained in the distended lungs is three hundred and five cubic inches, and only about one twentieth part of their contents is changed in every act of respiration. Such is the uncertainty, however, that reigns in this subject, that some physiologists are of opinion, that the air in the lungs is completely renewed in four acts of respiration. The volume of the air inhaled in every act of respiration is diminished in the lungs, about one eightieth part of its bulk. If we inspire forty cubic inches, one half cubic inch disappears; a loss which, perhaps, is occasioned by the absorption of a quantity of oxygen, above what is necessary for the production of the carbonic acid which is formed in respiration.

If an adult inhales forty cubic inches of air in

inspiration, he must inspire eight cubic inches of oxygen gas. If one-fifth of this be consumed in respiration, one and three-fifths cubic inches of oxygen gas disappear in every act of respiration. If, then, we respire twenty times a minute, we must consume thirty-two cubic inches of oxygen gas in the same time. It is probable, however, that forty cubic inches is much too high an estimate of the volume of the air inspired in ordinary respiration. If we assume it at fifteen cubic inches, which is not far from the average of several estimates made by different observers, it will follow that, if the quantity of oxygen consumed by respiration in a minute is thirty cubic inches, one half of that which is inspired, disappears in every act of respiration. For, fifteen cubic inches of atmospheric air, contain three cubic inches of oxygen. If half of this, i. e. one and a half cubic inches disappear, and we respire twenty times a minute, we shall consume thirty cubic inches in the same space of time. Davy estimates the quantity of oxygen, consumed in a minute by respiration, at 31.6 cubic inches. This would amount to nearly two thousand cubic inches in an hour, and forty-five thousand cubic inches in twenty-four hours. According to Lavoisier and Seguin, a man consumes in an hour, one cubic foot of oxygen, or in twenty-four hours, two pounds, one ounce, and one grain.

The quantity of carbonic acid discharged in every act of respiration, is very variable. By Goodwyn it is estimated at eleven per cent. of the whole volume of air expired; by Menzies, at only five per cent.; by Davy and Gay Luscac at three or four; by Contanceau at six or eight.

The quantity of carbonic acid, which is formed by respiration in twenty-four hours, is estimated at seventeen thousand, eight hundred and eleven grains, which would contain about five thousand grains, or nearly eleven ounces of carbon. This, in a year, would amount to about two hundred and fifty pounds solid carbon excreted from the body by the lungs. This estimate, however, there is reason to think, is

much too high. Prout supposes that the conversion of *albuminous matter* into *gelatin* is one of the principal sources of the carbonic acid, which is expelled from the lungs in respiration, and which he supposes to exist in the venous blood. Gelatin contains three or four per cent. less of carbon than albumen, and it enters into the structure of every solid part of the body, but exists neither in the blood, nor in any other of the animal fluids. The skin, especially, consists almost wholly of gelatin; a fact, from which Prout conjectures that a large part of the carbonic acid of venous blood is formed in the skin, and in the other gelatinous tissues. Accordingly we find that the skin gives off carbonic acid, and consumes oxygen.

The consumption of oxygen and the production of carbonic acid, are extremely variable under different circumstances, even in the same person. Whenever respiration is very active, more oxygen is consumed, and more carbonic acid formed. More carbonic acid is formed during digestion and during exercise; animal food and wine, and mental agitation increase it. According to Nysten, more carbonic acid is formed by respiration, in inflammatory fevers, and less, in atonic diseases. If pure oxygen gas be respired, a larger quantity of oxygen is consumed, and more carbonic acid expired, than in the respiration of atmospheric air. More carbonic acid is formed during the day, than in the night. The maximum quantity is formed between eleven o'clock, A. M. and one o'clock, P. M.; the minimum, about eight o'clock in the evening; from which time until half past three in the morning, there is no change.

The air expired from the lungs, is loaded with a large quantity of watery vapor, derived partly from the lungs, and partly from the mouth, fauces, and trachea. The quantity of it was estimated by Hales, at about twenty ounces in twenty-four hours; more recently by Menzies, at six; by Abernethy at nine; and by Thompson at nineteen ounces.

The breath frequently becomes impregnated with the odor of substances which have been swallowed.

If odoriforous substances are injected into the veins, or a serous cavity, the breath acquires this odor. If a solution of phosphorus in oil, be injected into the veins of an animal, its breath becomes luminous in the dark, and in the light is loaded with dense white fumes of phosphoric acid.

Vital part of Respiration.

By the vital part of respiration is meant, the changes produced in the blood by the influence of atmospheric air. The lungs digest air, as the stomach digests food; and, as the digestion of food is designed to form a nutritive fluid, the blood, out of aliment received into the stomach, the digestion of air contributes to the same object, the formation of blood. It completes what the stomach had begun. The nutritive fluid, formed by the stomach and its appendages and carried into the blood-vessels, is still imperfect, until it has passed through the lungs and received the influence of respiration. In the lungs it is supposed to lose a large quantity of carbon under the form of carbonic acid, and to absorb oxygen from the air, and to acquire its peculiar scarlet color; and it then becomes settled for all the purposes of life, and not before. The organization of the blood is probably completed in the lungs, perhaps by the addition of the red coloring matter, or hematosine. Respiration is, therefore, essential to the formation of the blood, which is the great excitant of the system, the fluid which keeps all the machinery of life in action, and which supplies the materials out of which all this machinery itself is manufactured. This is one essential purpose of respiration.

Another, equally important, and indeed closely connected with the first, is to produce certain changes upon the blood already formed, after it has circulated through the system, and been employed in the various functions of life. While the florid arterial blood is administering to the various operations of life, it is gradually changing its color, and becoming darker,

and at last, what remains of it, assumes the purple color of venous blood. In this condition it is no longer fit for the purposes of the animal economy. It is robbed of the principles most essential to life, and it must be renewed and prepared afresh, before it is fit to be employed again. For this purpose it is returned from all parts of the body to the heart, by the veins, and instead of being again transmitted to the various parts of the system by the arteries, it passes into the lungs, having received, just before its entrance into the heart, a supply of fresh prepared, nutritious matter, the chyle, mixed with the result of the vital decomposition of the organs and tissues of the system, part of which is probably designed to be remoulded again into the living tissues, and part to be eliminated from the system by the various excretions. In the lungs, it loses a large quantity of carbon and watery vapor and perhaps absorbs oxygen, and is changed back to its former scarlet color, and is then again fitted for the uses of the animal economy.

Respiration, therefore, in relation to its influence upon the blood, it appears, is a complex function. It completes the formation of the new blood; it renovates the old, preparing it again for the purposes of life; and it reconverts into blood the molecules detached from all the organs by vital decomposition, and which have consequently existed at least once before, under the form of blood. It incorporates the worn-out venous blood, both with matter imperfectly animalized, and with matter animalized to excess, and combines the heterogeneous mass into one homogeneous fluid highly impregnated with vitality, arterial blood.

Theory of Respiration.

There is still much difference of opinion among physiologists in regard to the mode, in which the changes produced in the blood, are effected by respiration.

An opinion, which prevailed for some time, assumed that the oxygen of the air inspired, combines

in the lungs with the carbon of the venous blood, and that the latter is converted into arterial blood by the loss of this carbon. This opinion was founded on the fact, that the volume of carbonic acid, formed in respiration, is almost exactly equal to the oxygen, which disappears; and as carbonic acid contains its own volume of oxygen gas, it was inferred that the oxygen which disappears, is converted into carbonic acid, by combining with carbon in the lungs. This carbon Mr. Ellis supposed to be separated from venous blood by a kind of secretion.

Another opinion, which has been maintained by several distinguished physiologists, is, that the oxygen is absorbed by the blood, and the carbonic acid is gradually formed in the course of the circulation, and is afterwards exhaled by the venous blood in a subsequent act of respiration. As the quantity of oxygen gas which disappears, is rather greater than sufficient for the production of the carbonic acid which is formed, it must be supposed that at least a part of the oxygen consumed, is absorbed by the blood; and if so, it seems probable that the whole of it is, and consequently, that the carbonic acid is not formed in the lungs at the expense of this oxygen, but is exhaled, ready formed, from the venous blood. A consideration which affords some confirmation to this opinion is, that the inhalation of oxygen is not necessary to the production of carbonic acid, as was ascertained by the experiments of Dr. Edwards on frogs and kittens;—for these animals, when confined in hydrogen gas, exhaled carbonic acid. Nysten and Contanceau, also, after inhaling azote, found in the air of expiration seven or eight per cent. of carbonic acid, just as when common air is respired. It is possible, however, as Rudolphi supposes, that this carbonic acid was formed from the atmospheric air, present in the lungs at the time of the experiments. Edwards's experiments, also, seem to have ascertained the fact, that the blood circulating in the lungs, is capable of absorbing oxygen as well as hydrogen and azote; and Nysten found that oxygen

gas might be injected into the veins of dogs without injury, provided but small doses were injected at a time; while the injection of azote and hydrogen, soon occasioned death. Some experiments of Girtanner seems to establish the presence of oxygen in arterial blood. He put some arterial blood of sheep under a receiver filled with pure azote; and at the expiration of thirty hours, the air in the receiver contained oxygen enough to support the combustion of a candle about two hours.*

That carbonic acid exists in venous blood, seems to be rendered probable from the fact, that carbonic acid may be injected in considerable quantity into the veins without injury. An experiment of Darwin has a bearing upon this subject, in proving that gaseous substances may probably exist in the blood in a state of loose combination. He found that venous blood, when exposed in an exhausted receiver, swelled to ten times its original bulk.

Another very plausible theory of respiration assumes, that the oxygen is absorbed by the radicles of the pulmonary veins; and that the carbonic acid and watery vapor are exhaled from the pulmonary mucous membrane. But the exhalation of aqueous vapor and of carbonic acid, is not regarded as peculiar to the lungs, and of course not as the essential and characteristic part of respiration; because the skin is constantly performing precisely the same office; since the matter of insensible perspiration contains both aqueous vapor and carbonic acid, combined with some animal matter. The exhalation of carbonic acid in respiration is not necessarily connected with the absorption of oxygen. Like other secretions, it is supposed to be formed from *arterial*, and not *venous* blood; to be secreted, not from the venous blood of the pulmonary artery, but from the branches of the bronchial arteries, distributed over the mucous membrane of the bronchia. While the essential and characteristic part of respiration, is supposed to consist

* Le Pelletier.

in the absorption of oxygen by the radicles of the pulmonary veins. In this view, the air drawn into the lungs in respiration, is decomposed; part of its oxygen is absorbed into the venous blood, and changes it to arterial. The roots of the pulmonary veins are the instruments of this absorption, and bring the oxygen into immediate contact with the venous blood. The carbonic acid, and the aqueous animal vapor, which exist in the air expired, are the product of a secretion from the mucous membrane of the brochia, a secretion from arterial blood, and perfectly similar to the exhalation from the skin. This secretion is not supposed to have any influence upon the arterialization of the blood in the lungs, because being formed from arterial blood, the effect of it should rather be, to convert this into venous, as is the case with the other secretions, than to change the venous into arterial blood. The lungs, in this view, are the seats of two opposite functions, absorption and exhalation. By the first, an aërial principle, necessary to life, is incessantly introduced into the animal economy, and constitutes the great and essential purpose of respiration. The *pulmonary* capillary system is the seat of this absorption. The second, which has its seat in the *general* capillary system, and which consists in the exhalation of carbonic acid, and a watery vapor, with a little animal matter from the lungs, is not peculiar to these organs, but is shared equally by the skin.

It may not be amiss to notice, in this place, the theory of Chaussier, who supposes that the oxygen is absorbed by the lymphatics of the lungs, vessels with which these organs are very abundantly supplied; that it is conveyed by the lymphatics into the thoracic duct, and there blended with the chyle and lymph; and afterwards, in combination with these fluids, conveyed to the right side of the heart, and thence transmitted to the lungs; and that it is in the extreme divisions of the pulmonary artery, that the combination becomes perfect. The change of color of the blood in the lungs, his theory supposes to be

occasioned merely by the separation of carbonic acid already existing in the venous blood. This theory, it will be perceived, transfers the process of hematosis from the lungs to the thoracic duct. It assumes, that the oxygen, before combining with the blood, passes through a great extent of the absorbent system, besides a part of the circulating, which is inconsistent with the suddennes of the change, which takes place in the blood in respiration. The venous blood acquires *instantly* the arterial color in the lungs—as was demonstrated by an experiment of Bichat. It also assumes, that the coloration of the blood in the lungs, is occasioned by the exhalation of carbonic acid. Now, according to Contanceau, during the respiration of any other gas than oxygen, especially of azote, the exhalation of carbonic acid and watery vapor continues, yet the venous blood retains its dark color.

Influence of Innervation upon Respiration.

The external organs of respiration, the nose, the mouth, the muscles about the chest, the diaphragm, and the abdominal muscles, are supplied with nervous influence by the fifth pair of nerves; the facial, the accessory, the spiral nerves, and the phrenic; while the proper organs of respiration, the larynx, the trachea, and its ramifications constituting the mass of the lungs, are supplied by the pneumogastric nerve, and the pulmonary plexus, which is formed by filaments of the pneumogastric nerve, and the anterior branches of the first thoracic ganglions.

The pneumogastric nerves, as might be inferred from their supplying all the internal organs of respiration with branches, exert an important influence upon respiration, though it still remains a subject of controversy with physiologists, what the precise nature of this influence is. The section of these nerves, on both sides, about the middle of the neck, soon occasions extreme dyspnea, followed, in a few hours, by death; and, on dissection, the lungs are found in a

state of great engorgement with blood, and the bronchial tubes filled with a white frothy fluid.

Death, in these cases, is owing to a paralysis of the muscles which open the glottis, while those which close this aperture remain unaffected. The *dilating* muscles of the larynx, receive their nerves from the inferior laryngeal, or the recurrent branch of the pneumogastric;—the constrictors, from the superior laryngeal. The section of this nerve paralyzes the constrictors, and the glottis remains open; while the section of the recurrent branch, paralyzes the dilators, and the glottis remains closed. It is said, that the section of the recurrent nerve, or that of the pneumogastric, between the superior and inferior laryngeal nerves, is more dangerous than the division of the par vagum, in the neck.

If, after the section of the pneumogastric nerve, an opening be made in the trachea, so as to admit the air freely into the lungs, the dyspnea is relieved, and life may be prolonged for three or four days. Yet the animal inevitably dies from increasing dyspnea, sometimes accompanied with vomiting. The blood in the arteries assumes a darker color, and, according to Mr. Brodie, less carbonic acid is evolved in respiration. Upon dissection, the lungs are found engorged with dark blood, and the bronchial cells and tubes, and frequently the trachea itself, are filled with a frothy, and sometimes bloody fluid. In some cases, there is also an effusion of serum, or blood, in the parenchyma of the lungs.

Different opinions have been entertained respecting the manner, in which asphyxia is produced by the section of the par vagum. It may be owing to one of two causes. Either the division of these nerves prevents the penetration of air into the bronchial cells, or it prevents the mutual action of the blood and air upon each other, and consequently, the arterialization of the blood. This latter opinion is adopted by Dupuytren, who thinks that animals die after the division of these nerves, because the air, though it still penetrates freely into the lungs, and comes in

contact with the blood, is unable to combine with this fluid, since this combination requires the vital action of the pneumogastric nerves. He endeavored to establish this opinion by experiment. He found that, if an artery in an animal in which the par vagum was divided, were opened, the blood which at first spirted out, of the bright arterial color, gradually became darker, and assumed the appearance of venous blood. The compression of the nerves produced the same effect. Le Gallois found, that an opening into the trachea, after the section of the pneumogastric nerves, did not prevent the arterial blood from becoming venous, though it permitted the free ingress of air into the lungs.

Dumas, however, found that, if air were forced into the lungs, after the section of the par vagum, arterial blood continued to be formed; from which he inferred that, in this experiment, asphyxia is occasioned by some obstruction to the entrance of air into the lungs; so that without some external force, this fluid is unable to penetrate into the bronchial cells. The fact, that after decapitation, life may be maintained for some time by artificial respiration, appears to be irreconcileable with Dupuytren's opinion.

The most probable opinion seems to be that of Brachet, viz. that the division of the par vagum annihilates the appetite of respiration, and paralyzes the fibres of the bronchia; permitting an accumulation of the bronchial secretions, in the cells and fine tubes of the lungs, and thus gradually preventing the contact of the air with the blood in the pulmonary vessels.

The experiments of Brachet appear to prove, that the pneumogastric nerves convey, from the lungs to the brain, a knowledge or sentiment of the want of respiration, in consequence of which the brain reacts upon the external muscles of respiration by means of the cerebro-spinal nerves, distributed to these muscles; and upon the muscles and fibrous coat of the larynx, trachea and bronchia, through the medium of the pneumogastric.

Brachet, in some of his experiments, found that the section of the par vagum, appeared to annihilate the appetite for respiration. In one of these, after the division of these nerves in a puppy three days old, he plunged the muzzle of the animal into warm water, so as entirely to prevent the entrance of air into his lungs. The animal made an effort to raise his head out of the water, and died in a state of asphyxia, after a few slight motions, which were wholly unlike the struggles for breath of a suffocating animal. The muzzle of another puppy of the same litter, was in like manner plunged in water, without the previous division of the per vagum. Unlike the first, he made violent efforts to withdraw his nose from the water, and to respire, and the asphyxia came on with difficulty, and was accompanied with convulsive struggles.

In two other comparative experiments, two puppies of the same litter were placed under two receivers, filled with atmospheric air, one of them having previously undergone the section of the pneumogastric nerves, and had an opening made in the trachea; the other without any preparation. In the latter, respiration soon became larger and more frequent, the animal raised his head, and breathed with his mouth open and his nostrils expanded, and died with the symptoms which usually accompany this kind of asphyxia. The former, in which the par vagum had been divided, breathed in the usual manner, and died quietly at the expiration of forty-six minutes, without agitation, and without expanding his nostrils or opening his mouth.

From these experiments Brachet infers, that the section of the par vagum intercepts the impression produced by the privation of atmospheric air, in its passage to the brain; since one animal who has been subjected to this experiment, dies of asphyxia, without manifesting any feeling of the want of respiration. The continuation of the movements of respiration, after the appetite has been annihilated, Brachet attributes to the habit, which the respiratory

muscles, have acquired of contracting, and which survives the sentiment of the want of respiration. The convulsive struggles which sometimes occur in this kind of asphyxia, he attributes to the influence of the black blood on the heart and other organs.

Brachet also attempts to establish, that the par vagum apprizes the brain of the presence of mucus, or any foreign substance in the bronchia, and that by means of the same nerves, the fibres of the bronchia react upon and expel these substances. He divided the two pneumogastric nerves in a dog, and then made an opening into the trachea, through which he introduced a little ball of orris (boule d'iris) fastened to a thread. The breathing became laborious, but the animal exhibited no sign, that he experienced any disagreeable sensation. He then held an open jar of muriatic acid to the opening in the trachea for several minutes, and even let some drops of it fall into the interior of it, but without eliciting from the dog any signs of sensation.

In another experiment, he made an opening in the trachea of a dog, without dividing the par vagum. A few drops of blood fell into the trachea and excited coughing. The ball of orris excited violent coughing, which pushed it forcibly towards the larynx. The muriatic acid occasioned paroxysms of coughing, which obliged him to withdraw it. On applying it again, the cough was renewed—upon which Brachet divided the par vagum, when the cough suddenly ceased, respiration became rattling, and in less than an hour, the dog died without having expectorated any thing.

That these nerves react upon the fibres of the bronchia, causing them to contract, Brachet endeavors to prove by experiment. He injected warm water into the trachea of a dog, which excited violent coughing, by which the water was expectorated. The irritation, however, provoked an abundant secretion, which kept up the cough and expectoration for several hours. Upon repeating the experiment, the next day, on the same dog, the same phenomena occurred; but after

the dog had apparently rejected all the water from his lungs, Brachet divided the par vagum, upon which expectoration immediately ceased, respiration became rattling, and in about two hours the dog died.

Le Pelletier also remarks, that the section of the *par vagum*, or a suspension or diminution of its power, causes a debility or inaction of the air vesicles, and a stagnation in them of the air, altered by hematosis; and it explains the occurrence of asphyxia in certain cases, where the great phenomena of inspiration and expiration continue to be carried on. For the air may continue to be renewed in the principal divisions of the bronchia, by the mechanical movements of respiration; but its renovation in their ultimate branches, is impossible, without the vital contraction of the air vesicles themselves.

CHAPTER XVI.

The Nutritive Functions.

The nutritive functions are four in number, viz. *Digestion, Absorption, Secretion, and Nutrition.*

Digestion.

Digestion is a function peculiar to animals; and the existence of a separate set of organs, devoted to digestion, has been regarded as one of the characteristics, by which animals are distinguished from plants. Vegetables, it is true, are nourished and grow; but they do not, properly speaking, *digest.* Their nutrition and growth are the result of an external absorption from the atmosphere and the soil, effected at

their surface, and by means of roots; while animals first receive the materials of their nutrition into a central cavity, where they are subjected to a series of remarkable changes, and their nutritive elements are *afterwards* carefully selected, and imbibed by a set of *internal* roots. Nutritive matter, therefore, is absorbed in a crude state by plants; but in a digested state, by animals. In vegetables, and the lowest orders of the animal kingdom, the absorbing vessels themselves, exercise an assimilating power over the matters absorbed as nourishment, and this preparation is the only digestion which the food of these kinds of organized matter, undergoes; but in all the animal kingdom, with the exception of the very lowest orders in the zoological scale, digestion is centralized in a particular apparatus, more or less complicated, according to the position of the species in the scale of animal life.

In its simplest or rudimental state, the digestive apparatus consists of a membranous sac, provided with a single opening, which serves both for mouth and anus. In its first stage of complication, it assumes the form of a straight canal, the length of which is less than that of the animal to which it belongs, and is provided with *two* orifices, one destined for the reception of the food, the other to the expulsion of the refuse matter of nutrition. In its higher stages of complication, it progressively acquires a greater relative length, in some of the higher orders of animals, exceeding, by nearly thirty times, the length of the body, and presenting numerous convolutions. Its two orifices are guarded by circular muscles, which act under the control of the will; and several auxiliary organs are connected with it, which contribute to give greater variety and complication to its functions.

In the *mammalia*, the digestive canal presents its greatest or last degree of complication. In the human species it consists of a tube, about six times as long as the body, extending from the mouth, through the chest and abdomen, to its inferior orifice, the

anus; unequal in its diameter, being much larger in some places than in others, and in one part swelling out into a capacious sac; presenting, in a great part of its course, irregular convolutions, and terminating at each extremity by one orifice, closed by a circular muscle, which acts under the control of the will.

The digestive canal is found partly in the head, where it forms the cavity of the mouth; partly in the neck and thorax, where it takes the names of the *pharynx* and the *œsophagus;* but principally in the abdomen, where it forms the stomach and intestines, which, with the associated viscera, the liver, the pancreas, the spleen, and the mesentery, occupy nearly the whole of this great cavity.

The mouth is formed by the two lips. Its cavity is bounded above by the palate, below by the tongue, before by the teeth, laterally by the cheeks, and posteriorly by the curtain of the palate, which separates the cavity of the mouth from the *pharynx.* The pharynx is a tunnel-shaped cavity, which terminates in the *œsophagus.* It opens into the mouth by the isthmus of the fauces; into the nasal cavities by the posterior nares; into the trachea, by the superior opening of the larynx; and into each ear, by a funnel-shaped canal, called the *Eustachian tube.* The *œsophagus,* or gullet, is a continuation of the pharynx. It is a long, straight, fleshy tube, which passes down the chest, behind the trachea, lying upon the vertebral column; and it opens into the stomach by an orifice, which is called the *cardia.* The pharynx and œsophagus, or the pharyngo-œsophageal cavity, is the organ of deglutition.

The stomach is a large pouch, situated below the diaphragm, and lying obliquely across the epigastric region, and a part of the left hypochondriac. Above, it is bounded by the liver and the diaphragm; below, by the transverse colon; behind, by a part of the vertebral column, and the great centre of the ganglionic nerves; before, by the false ribs of the left side, with their cartilages; on the left, by the spleen.

The stomach has two orifices, a superior and an

inferior. By the former, which is also called the *cardiac*, it communicates with the œsophagus; by the latter, also termed the *pyloric*, it opens into the first of the small intestines, or the *duodenum*. Two curved lines, a superior and an inferior, extend from one of these orifices to the other. The superior, which is concave, is much shorter than the inferior, which is convex; i. e. the inferior arch of the stomach is much greater than the superior. The situation of the organ, as well as its volume, varies much, according to its state of emptiness or repletion. When empty, it is flaccid and depending, and its greater curvature inclines downward. But, when distended, its greater curvature is raised forward. The stomach is the organ of *chymification*, or gastric digestion.

The intestines extend from the pylorus to the anus, forming a mass of convolutions, which fill most of the abdominal cavity. They are usually divided into two portions, viz. the large and the small intestines; a distinction founded on their relative diameters. The small intestines, or the upper portion, are subdivided into three parts, viz. the *duodenum*, the *jejunum*, and the *ilium*. The first receives its name from its length, which is equal to twelve fingers' breadths. It is the seat of *chylification*, or duodenal digestion. The *jejunum*, or hungry gut, is so called from its being generally found empty; and the *ilium*, i. e. the twisted gut, derives its name from the numerous convolutions which it exhibits. The small intestines have a less diameter and thinner coats, than the other portions of the intestinal canal; but their length is much greater, amounting, in an adult, to four or five times the length of the whole body. They are attached to the superior lumbar vertebræ by a duplicature of the peritoneum, called *the mesentery*. The large intestines commence where the small terminate. A circular fold of the mucous membrane of the ileum, penetrating, by its free border, into the large intestine, and called the ileo-cæcal valve, separates the two great divisions of the intestinal canal from each other. The large intestines are divided into three

portions, viz. the *cæcum*, the *colon*, and the *rectum*, which last terminates in the anus.

In the greater part of its extent, the digestive canal consists of three membranes, viz. a mucous, a muscular, and a serous. Only the two first, however, are essential to it; the mucous, or internal tunic, constituting a secreting and absorbing surface; and the muscular, or middle, executing the various motions to which the food is subjected after its reception into the mouth. The external, or serous tunic, is merely accessary, as it is wanting in many parts of the digestive tube, and no where completely envelopes it.

The soft parts of the mouth are composed almost wholly of muscles, lined internally by a mucous membrane. These muscles execute the different motions of the mouth, by which this cavity is enlarged or diminished, and variously modified in its shape, in the processes of mastication and insalivation, and the food is afterwards forced from the mouth into the pharynx. The membrane which lines the mouth, secretes a mucus, which lubricates this cavity, and is blended with the food in mastication.

The muscular part of the pharynx is composed of six constrictor muscles, which contract this cavity and compress its contents, forcing them into the œsophagus in the act of deglutition. The fibres of these muscles form planes or sheets, which cross each other in various directions. The pharynx is lined internally by a mucous membrane, of a deep red color.

The œsophagus, in like manner, is composed of a muscular coat and a mucous membrane. The former consists of two strata of muscles, viz. one external, which is composed of longitudinal fibres, of considerable thickness and strength; and one internal, consisting of circular fibres, considerably thinner than the former. Near the stomach the longitudinal fibres diverge, and may be traced extending over its cardiac extremity; but the circular fibres wholly disappear at the termination of the œsophagus. The mucous membrane is continuous with that which lines the pharynx.

It presents numerous longitudinal folds, which are owing to the contraction of the muscular coat.

According to Magendie, the inferior third of the œsophagus, is subject to an uninterrupted alternate motion of contraction and relaxation. The contraction commences at the upper part of the inferior third, and proceeds, with a certain degree of rapidity, to the insertion of the œsophagus into the stomach. Its duration is variable, but on an average amounts to about thirty seconds. The part thus contracted is hard and elastic, like a tense cord. The relaxation, which succeeds, takes place suddenly and simultaneously in the contracted fibres. This motion of the œsophagus is under the influence of the par vagum. If these nerves are divided in an animal, the œsophagus ceases to contract in the manner just described, and assumes a state intermediate between contraction and relaxation.*

The œsophagus is furnished with mucous follicles, which are sparingly distributed over it.

The stomach, also, is composed of two principal coats, or membranous laminæ. The internal is a soft, spongy, mucous membrane, which is extremely vascular, or plentifully supplied with blood-vessels. Except when the stomach is distended, the mucous membrane is drawn into folds or wrinkles, so that its surface is much greater than that of the other coats. It is smeared with mucus, secreted by numerous follicles, seated in its mucous coat.

The second coat of the stomach is muscular, and is composed of fibres, disposed in three different directions, viz. longitudinally, circularly, and obliquely. The longitudinal fibres form the exterior muscular plane. Immediately beneath this are the circular fibres, which run parallel to one another; and subjacent to the latter are the oblique, which form broad fasciculi at the two extremities of the stomach. Besides these two principal coats, the stomach receives an external tunic, formed by a duplicature of the

* Magendie.

peritoneum. This coat is united to the muscular, by cellular tissue.

The stomach is plentifully supplied with blood-vessels and nerves. The blood is chiefly designed to furnish materials for the secretion of the gastric fluid, which is supposed to be the principal agent in chymification. The arteries of the stomach are very large and numerous, and they all spring, directly or indirectly, from a large trunk, called the cœliac artery. The nerves of the stomach originate from both nervous systems, the cerebro-spinal and the ganglionic. From the former, it receives branches by means of the pneumogastric; and from the latter, by the cœliac plexus.

The structure of the intestines resembles, very nearly, that of the stomach. They are composed, essentially, of two coats, viz. a mucous and a muscular; the former constituting a secreting and absorbing surface; the latter, or muscular, executing the various motions, which are necessary in propelling the contents of the intestines regularly through the canal. There is a third tunic, which is external, and which is derived from the peritoneum. This is termed the serous, or peritoneal coat.

The mucous coat is sometimes termed *villous*, from the villosities which its internal surface exhibits, resembling the pile of velvet. These villi are extremely numerous, presenting the appearance of small spongy masses, adhering to the mucous coat. They are very vascular, and their bases are surrounded by small bodies of a glandular structure, termed mucous follicles, which are destined to secrete the mucus, which smears the inner surface of the intestines.

The mucous coat of the small intestines is gathered into folds or plica, presenting, when dried, a lunated appearance, and denominated the *valvulæ conniventes*. These appear to be designed to increase the internal surface of the intestines, and to retard the passage of the alimentary matter, so as to give more time for the necessary changes to be wrought upon it, and also for its absorption by the lacteals.

The muscular coat consists of two orders of fibres, one longitudinal, or running parallel to the axis of the canal; the other circular, or embracing it like rings. In the large intestines, the longitudinal fibres are collected into bundles, or fasciculi, which have the effect of puckering up the intestines, forming numerous prominent cells, in which feculent matter is sometimes retained a long time.

The arteries of the intestines are derived from the mesenteric arteries; their nerves almost wholly from the solar plexus. Into the first of the small intestines, the duodenum, open the excretory ducts of two important glands, the liver and the pancreas.

The necessity of taking food arises from the losses, which the body is constantly undergoing by the different secretions and excretions, and which amount to several pounds in the space of twenty-four hours. These losses immediately affect the blood, which becomes impoverished by the demands upon its principles, which nutrition, and the various secretions and excretions, are constantly making. But, indirectly, the solids feel the effects of this incessant drainage, because they are undergoing, without intermission, the process of organic decomposition, and the molecules detached from them, are passing into the venous blood, and are afterwards eliminated from the system by the urinary and other excretions.

We are incited to take food by certain internal sensations, which are termed hunger and thirst. Neither the seat nor the efficient causes of these sensations are well known. Hunger has been frequently referred to a peculiar affection of the nerves of the stomach; an opinion which in itself seems sufficiently probable, as sensation is a phenomenon of the nervous system, and as the sensation of hunger is referred directly to the stomach. The experiments of Brachet, in which the section of the pneumogastric nerves appeared to annihilate the appetite for food, tend to corroborate this opinion. It is observed, however, by Mayo, that nausea is referred to the stomach upon the same grounds with the sensation of hunger; and yet,

according to the experiments of Magendie, nausea and retching may be produced after the removal of the stomach of an animal, by injecting tartar emetic into the veins.

Thirst has been referred to a certain impression upon the nerves of the fauces and pharynx. But in the case of a man, who had cut through the œsophagus, several buckets full of water were swallowed daily, and discharged through the wound, without quenching the thirst,—which was afterwards allayed by injecting spirit, diluted with water, into the stomach. From these facts Mayo observes, that it is not impossible, that a person might be hungry without a stomach, and thirsty without a throat.

Digestion, from the first reception of aliment into the mouth, to the rejection of the refuse of it by the inferior extremity of the intestinal canal, is composed of the following processes, viz.—1. *manducation* and *insalivation*, performed by the mouth; 2. *deglutition*, by the pharynx and œsophagus; 3. *chymosis*, by the stomach; 4. *chylosis*, by the duodenum; 5. intestinal *absorption*, by the small intestines; and 6. *defecation*, by the large.

I. *Manducation* is the mechanical division of the food, which is broken and ground down by the action of the teeth, pressed against it by the motions of the jaws. These motions are of three kinds, viz. one vertical, consisting in the elevation and depression of the lower jaw, and two horizontal, in one of which the lower jaw is moved backwards and forwards, and in the other laterally, or from side to side. These motions are executed by the action of several muscles, viz. the temporal, the masseter, the external and internal pterygoid, the zygomatic, the digastric, and some others. The temporal, masseter and internal pterygoid muscles, elevate the lower jaw, the temporal moving it somewhat backwards as well as upwards; the masseter, forwards and upwards, and the pterygoid, from side to side. In carniverous animals, these muscles, particularly the temporal, possess prodigious power. The lower jaw is moved

horizontally forward, by the combined action of the two external pterygoid muscles, aided by the masseter and the internal pterygoid. The pterygoid muscles, when they act singly, move the jaw obliquely, from side to side, and communicate a grinding motion to the teeth.

The lower jaw is depressed, and the mouth thus opened by the action of several muscles, especially the digastric, and various others, attached to the os hyoides.

During the operation of mastication, in which the food is divided and ground down by the teeth, it is intimately penetrated and impregnated with the saliva, a fluid which is secreted by three pairs of glands, viz. the parotids, the submaxillary, and the sublingual. These glands are stimulated to an increased secretion of saliva, by the taste or smell, and frequently by the mere idea of food. These glands will be described hereafter.

The quantity of saliva secreted during an ordinary meal, is probably very considerable. In a case of division of the œsophagus, described by Dr. Gairdner, from six to eight ounces of saliva were observed to be discharged during a meal, which consisted of broth, injected into the stomach through the wound. Under the stimulus of mastication, as Mayo remarks, the quantity secreted is probably much greater.

The minute division of the food by mastication, and its penetration by the saliva, appear to be designed, chiefly, to promote its solution in the stomach, and to facilitate deglutition. Hence, a leisurely and sufficiently prolonged mastication, in general, renders digestion easier and more prompt.

II. *Deglutition.* After the morsel is sufficiently masticated, it is pushed into the pharynx by the action of the tongue, which is raised and pressed against the palate by the *stylo-glossal* muscles. At the same time, the pharynx is drawn upwards to receive the morsel by the action of the muscles, which raise the *os hyoides*, and by the *stylo-pharyngeus.* The pharynx is embraced by the fibres of three mus-

cles, which are termed its upper, middle, and lower *constrictors;* the contraction of which, tends to diminish its cavity and to compress its contents; and their successive action gradually forces the bolus into the œsophagus. Its return into the mouth is prevented by the pressure of the tongue; its entrance into the posterior nares is precluded by the velum pendulum palati, which is forced before the bolus, and becomes horizontal and tense by the action of the *levator* and the *circumflexus* of the palate; and its passage into the larynx is prevented by the epiglottis, which is pressed down by the food upon the orifice of the larynx. According to Magendie, however, the epiglottis is not necessary to deglutition; for, in some of his experiments, it was removed from animals, and it has sometimes been destroyed by disease in the human subject, without materially impairing deglutition. The passage of food into the larynx, according to Magendie, is prevented by the action of the muscles which close the *rima glottidis*, viz.; the *arytænoideus transversus*, and the *arytænoidei obliqui*. As long as these muscles preserve their power of contraction, food is prevented from passing into the larynx, even in the absence of the epiglottis. But if the power of contraction in these muscles be destroyed or enfeebled, as appears to be the fact in some cases of palsy, deglutition is liable to be interrupted by violent fits of coughing, occasioned by the entrance of a part of the food into the larynx—although the epiglottis remains entire.

As soon as the food has reached the œsophagus, the muscular contraction of this fleshy tube is excited, by means of which the bolus is gradually forced into the stomach. The power of gravitation contributes but little to the descent of food into the stomach; for it is found that funambulists can swallow without difficulty, with their heads downward. The motion of the œsophagus in deglutition, consists in a successive contraction of its circular fibres, from above downwards. The upper part of the tube is dilated by the bolus, which is forced into it by the contraction of

the pharynx. Its superior circular fibres are then excited to contract, and the food is pushed further down into the tube, dilating the parts immediately beneath, which react upon it, and force it still further down, until it reaches the stomach. The longitudinal fibres, in contracting, shorten and relax the œsophagus, and in this mode promote the descent of its contents. Mayo supposes that the longitudinal fibres of the two extremities of the alimentary canal, viz. the œsophagus and the rectum, are designed to strengthen these parts, and to prevent their elongation and rupture by the volume of their solid contents.

Deglutition is divided by Magendie, into three stages, viz.—1. the passage of the food from the mouth into the pharynx; 2. from the pharynx into the œsophagus; and 3. from the œsophagus into the stomach. The first stage is voluntary; the second partakes of the nature both of voluntary and involuntary action. Magendie considers pharyngeal deglutition as involuntary; yet Mayo remarks, that it may at any time be performed by a deliberate exertion of the will. The third stage, or œsophageal deglutition, is removed from the jurisdiction of the will. Yet, as Mayo remarks, the œsophagus appears to partake of the nature both of the voluntary and involuntary muscles; for when the nervi vagi are pinched, a *sudden* action ensues in its fibres, which is presently after succeeded by a second action of a slower kind.

III. *Chymosis.* Gastric digestion, or chymosis, consists in the conversion of food in the stomach, into a soft, pulpy mass, termed *chyme.* The aliment, previously masticated and thoroughly blended with the saliva, descends through the pharynx and œsophagus into the stomach, in the manner just described. Some physiologists suppose, that the stomach is not mechanically distended by the mass of the aliments, but that it exercises the power of self-dilatation in the reception of the food. However this may be, the organ enlarges in proportion to the volume of the food which is swallowed. Its coats are distended, the plica of its mucous membrane are unfolded, and the sinuosities of

its arteries and veins disappear. The increased volume of the stomach pushes the diaphragm up into the thorax, distends the walls of the abdomen anteriorly, and presses against the contiguous viscera, particularly the liver and spleen. The position of the stomach undergoes a change, the organ performing, as it were, part of a revolution on its axis, by which its anterior face becomes superior, its posterior inclines downward, its inferior arch is raised forward, and its superior turned backward.

Motions of the Stomach.

The stomach, stimulated by the presence of food, reacts upon and compresses it. Its muscular coat exerts a kind of vermicular motion, by the alternate contractions of its transverse and longitudinal fibres, the former diminishing its diameter, the latter shortening its length, by approximating its splenic and pyloric extremities. Tiedemann and Gmelin remark, that the muscular coat of the stomach does not contract simultaneously throughout its whole extent, but one part contracts a little, while another dilates, and vice versâ; the place where contractions take place becoming thicker and rugous. According to the same physiologists, these undulatory movements proceed from the œsophagus towards the pylorus, and from this back again to the œsophagus. In some cases, they observed these motions to begin at the same time at both extremities of the stomach, and to meet at the middle of the organ. They appeared to be most energetic in the pyloric part of the stomach, where the muscular coat is thickest. The most vigorous contractions were occasioned by the most stimulating food. These successive contractions of the muscular fibres occasion a slow movement of the aliments in the stomach, by which they are brought successively into contact with all parts of its surface, and thoroughly penetrated with the gastric fluid.

According to Beaumont, the contractions of the muscular coat of the stomach produce a constant,

slow revolution of the food round the interior of the organ, from one extremity to the other. After its entrance into the stomach, the ordinary course of the food, in these revolutions, is first from right to left, along the small arch, thence along the large curvature, from left to right. "The bolus, as it enters the cardia, turns to the left, passes the aperture, descends into the splenic extremity, and follows the great curvature towards the pyloric end. It then returns in the course of the smaller curvature, makes its appearance again at the aperture, in its descent into the great curvature, to perform similar revolutions." * From one to three minutes are occupied in completing one of these revolutions. During these motions, the cardiac and pyloric orifices of the stomach are closed, so as to prevent the escape of the food. The contraction of these apertures continues, even if the stomach be cut out of a living animal, during digestion. According to Home, the stomach, during these contractions, forms a kind of double sac, by the action of a *transverse* band, situated three or four inches from the pyloric extremity. The contraction of this band during digestion, divides the sac of the stomach into two parts, one of which, viz. *the splenic*, contains the food that is but little digested; the other, or *the pyloric*, that part of it, which is further advanced in chymification. This opinion, Beaumont's experiments confirm.

Secretions of the Stomach.

Not only the muscular action of the stomach is excited by the stimulus of food, but its circulation and its secretions are increased. There is a concentration of vital activity in the organ, an increased afflux of blood towards it, a greater evolution of heat, and an increase of its follicular and perspiratory secretions. The latter of these, the gastric fluid, is exhaled in abundance, and the process of digestion commences.

* Beaumont.

In the process of chymification, the food undergoes a remarkable change; for, the properties of chyme are entirely different from those of the aliment out of which it is prepared. The taste, smell, and other sensible properties of the food, are altered or disappear, and new ones are acquired. It is evident, therefore, that the chemical affinities of the food have been totally subverted, and its elements have entered into new combinations. Whether this change is confined to the proximate principles of the food, or extends to its ultimate elements, it is not easy to determine. *This* remarkable change in the properties of the food, is produced by a fluid, secreted by the stomach, called the gastric liquor. This fluid is secreted abundantly during digestion, but not when the stomach is empty. It has already been observed, that the stomach is largely supplied with blood-vessels. It receives much more blood than is necessary for its own nutrition; and the destination of this excess of blood, probably is to furnish materials for the secretion of the gastric fluid. The gastric liquor is produced not by a follicular secretion, but arterial exhalation. Like all the other secretions, it may be increased, diminished, or changed in its qualities, by various causes. Thus the division of the pneumogastric nerves, the use of narcotics, the excessive use of stimulating drinks, violent emotions of the mind, &c. diminish the secretion of this fluid; and, on the other hand, condiments and high seasoned food increases it.

The gastric fluid, according to Beaumont's observations, is a clear transparent fluid, perceptibly acid to the taste, and a little saltish, but destitute of odor. It effervesces slightly with the alkalies; possesses, in a high degree, the property of coagulating albumen; is powerfully antiseptic, resisting the putrefaction of animal matter; and is an effectual solvent of alimentary substances. Its acid properties are owing to the presence of free muriatic and acetic acids. According to Tiedemann and Gmelin, the gastric fluid contains the hydrochloric and acetic acids, and in horses, the butyric; saliva, osmazome, chloruret, and sulphate of

soda, and a little carbonate and phosphate of lime. The degree of its acidity corresponds to the less or greater digestibility of the food; those aliments which are the most difficult of digestion, causing a greater degree of acidity in the gastric fluid. Thus, bones, cartilages, fibrin, concrete albumen, meat, gluten, oats and bread, are more difficult to digest than starch, potatoes, rice, gelatin, and liquid albumen; and they were found to occasion the secretion of a more acid gastric fluid in dogs and cats. In horses, oats caused the secretion of a very acid gastric liquor. It appears, then, that the degree of acidity of this fluid, depends on the degree of excitation of the stomach, produced by the food. The gastric liquor appears to be secreted only when the stomach is excited by the stimulus of aliment; and, consequently, no conclusion respecting its properties, can be drawn from experiments on the fluid, taken from the stomach during fasting, as this consists chiefly of gastric mucus, mixed with saliva; a consideration, which may account for many contradictory results in the researches of physiologists on the gastric fluid. Now, this fluid appears to be the principal agent in gastric digestion, or chymification. Its powers in dissolving alimentary substances, were first satisfactorily ascertained, by some experiments performed by Spalanzani and Stephens, in the last century. Stephens, in his experiments, inclosed various alimentary substances in hollow metallic balls, pierced with holes, to admit the gastric fluid; and he found that the balls, when voided by stool, were empty, the substances they had contained being digested, having escaped by the holes in their sides. These experiments were performed on men and other animals. Spalanzani obtained similar results; and pursuing the idea, he exposed certain aliments, properly masticated and impregnated with saliva, to the action of the gastric fluid *out of the stomach.* They were kept in the axilla for several hours; and upon examination, afterwards, were found to be chymified. Beaumont's experiments appear to establish, conclusively, the power of the gastric liquor in

dissolving alimentary substances out of the stomach. The process is rather slower, perhaps, because the exact temperature of the stomach cannot be accurately maintained by artificial means, and because it is impossible to subject the food to the same mechanical agitation, by exactly imitating the motions of the stomach. The results, however, are in both cases apparently the same; the chyme, prepared by artificial digestion, presenting the same sensible properties, as that which is found in the stomach. The solvent powers of the gastric fluid, in respect to alimentary matter, are very great. The hardest bones are dissolved and digested by it in the stomachs of dogs; and Beaumont found that it would dissolve even bones out of the body. It coagulates milk, and the serum of the blood, and other kinds of albumen; and afterwards dissolves the coagula. A certain degree of heat is necessary to its action, and it operates with more energy, the more minutely the food is divided.

The solvent powers of this secretion, in relation to alimentary substances, may be understood, in part, by a reference to its composition. Thus, the water which it contains dissolves several simple alimentary principles, as liquid albumen, gelatin, osmazome, sugar, gum, and starch. The hydrochloric and acetic acids, dissolve several other principles, which are not soluble in water; as concrete albumen, fibrin, coagulated caseum, gluten, and gliadine, a substance analogous to gluten. These acids dissolve, also, cellular tissue, membranes, tendons, cartilages and bones. Their solvent power is assisted by heat; and hence, the temperature of the stomach is an important agent in gastric digestion. From the fact, that alimentary substances, when subjected to the action of the gastric fluid out of the stomach, are converted into a substance presenting the characters of chyme, some physiologists have embraced the opinion, that gastric digestion is nothing but a chemical solution of the aliment in the gastric fluid. Tiedemann and Gmelin, who adopt this opinion, admit however, that, with

respect to some alimentary substances, a peculiar kind of decomposition is produced by the action of the gastric fluid. Starch, for instance, when dissolved in the stomach, loses its peculiar property of giving a deep blue color to iodine, and is converted into sugar and gum.

It would follow, from this theory of digestion, that the digestibility of aliments, is in proportion to the facility with which they are dissolved in the gastric liquor, and, of course, to their peculiar composition. The substances most easy of digestion, are such as are soluble in warm water, or contain a large proportion of soluble principles, as sugar, gum, liquid albumen, and gelatin. Those which require the aid of acids to dissolve them, as those which contain much gluten, concrete albumen, fibrin and caseum, cartilage, bone, are of more difficult digestion; while some are insoluble in the gastric fluid, and of course indigestible; as the fibres of wood, or of plants, the skin of some of the leguminous plants, the kernels of fruits, feathers, hairs, &c. Chymification, however, is not to be regarded merely as a chemical solution of alimentary matter in the gastric fluid. It is true, that the process of gastric digestion may be imitated out of the body, by macerating alimentary substances in the gastric fluid. No doubt a solution more or less perfect, may be effected in this way, by the solvent powers of this fluid over substances of an alimentary kind. This is established by the experiments of Spalanzani, and more fully by those of Beaumont. But it is not so certain, that they become endued with all the properties of chyme, especially with those which assimilate them to the nature of the living animal body, by undergoing this process. Le Pelletier affirms, that in the experiments, which he had made with food, thoroughly masticated, and blended with saliva, penetrated with gastric fluid, and placed in favorable circumstances out of the stomach, he always found the food either reduced to a pulpy mass, or simply softened, or in the incipient stage of acid or putrid fermentation; but never in a state of *perfect*

chyme; as was proved by introducing the artificial chyme into the duodenum of living animals, when it was found that not a particle of real chyle was ever formed from it. It is indeed difficult to conceive how a mere *chemical* solution of aliment can endue it with living properties, or *vitalize* it; for, undoubtedly, chyme is in the first stage of animalization. It cannot become invested with living powers, if placed out of the *atmosphere* of vitality. Vital affinity can operate only within the sphere of vital power. If, then, the gastric fluid is a mere chemical solvent of alimentary substances, it seems probable that the living coats of the stomach, with which all parts of the food are brought successively into contact, may impart to the latter certain properties, which may assimilate it to the nature of the living organization; properties which it is impossible to conceive that it can acquire, when removed from the contact of living matter. Life is a unit, its properties cannot be separated from the source whence they originate. It is as impossible to conceive of bottling up a portion of vitality with a few ounces of gastric fluid, as it would be to think of corking up a phial of sunshine, and keeping it in the dark.

The analysis of digestion, proposed by Prout, corresponds in the main with this view. Prout attributes to the stomach, three distinct powers; which are all exerted in digestion; viz. a *reducing*, a *converting*, and a *vitalizing* power. By the reducing power, he means the faculty which the stomach possesses of dissolving alimentary substances, or of bringing them to a semifluid state. This operation he supposes to be altogether chemical. By the converting power of the stomach, he means the faculty of changing simple alimentary principles, into one another, as starch into sugar and gum. Without such a power, Prout thinks, that the uniformity in the composition of the chyle, which he supposes to be indispensable to the existence of animals, could not be preserved. This process of *conversion* he considers, also, as chemical, but as of more difficult accomplishment than the reducing. The

vitalizing, or *organizing* power, is that by which alimentary substances are brought into such a condition, as adapts them for an intimate union with the living body. This power, he says, cannot be chemical, but is of a vital character, and its nature is entirely unknown. The vital properties which the chyme acquires in the stomach, whatever these properties be, it is the prerogative of the living or the nervous powers of the stomach to confer. The influence of these powers in digestion, is illustrated by numerous facts, especially by the influence of these medicinal agents which depress the nervous energy, as opium and other narcotics; the effect of passions of the mind, and the sudden accession of disease; and intercepting the nervous influence by the ligature, or section of the parvagum; causes, which can hardly be supposed competent to destroy the chemical or solvent powers of the gastric fluid, but which, nevertheless, are well known by physiologists, to interrupt or weaken the process of gastric digestion.

The substance into which aliment is connected in the stomach, is called *chyme.* This is a semifluid, homogeneous matter, of a grayish color, sourish smell, and insipid or disagreeable taste, but varying considerably in its sensible properties, according to the qualities of the food out of which it is prepared. According to Beaumont, it is invariably homogeneous, but its color partakes slightly of the color of the food. "It is always of a lightish or grayish color, varying in its shades and appearance, from that of cream, to a grayish or dark-colored ground. It is, also, more consistent at one time, than at another; modified in this respect, by the kind of diet used. It is invariably distinctly acid." Its acidity, according to Tiedemann, is derived from that of the gastric fluid. Leuret and Lassaigne, found the chyme in an epileptic, who died five hours after taking food, to present the appearance of a pale saffron-colored pap, of a strong and repulsive smell, containing lactic acid, a white crystaline animal matter, similar to sugar of milk, a fat yellowish acid matter, resembling rancid butter; another

animal substance, like caseum, albumine, phosphat of lime, muriate and phosphat of soda. The time required for the conversion of food into chyme, varies according to the greater or less degree of digestibility of the latter. In Beaumont's experiments, the average time employed in gastric digestion, was about three hours and a half. If the food is of a soft consistence, and well divided by mastication, it is speedily penetrated by the gastric fluid, and rapidly dissolved. But if it possesses a certain degree of consistence, or has been swallowed in large masses, its solution goes on slowly, and from the surface to the centre. The external layers are frequently softened, and almost dissolved, while the parts within are almost wholly unchanged. Those parts of the aliments, which are nearest the surface of the stomach, are most exposed to the action of the gastric fluid, as well as to the vitalizing influence of the stomach, and of course are the soonest dissolved, and chymified.

By the successive contractions of the muscular coat, the dissolved portions are carried towards the pylorus, and gradually pass out of the stomach into the duodenum. The passage of the chyme from the stomach takes place during the expansion of the circular fibres of the pyloric extremity, perhaps by the contraction of the longitudinal. It is at first slow, but becomes more rapid in the later stages of chymification, as the formation of chyme becomes more abundant. According to Rudolphi, the chyme passes out of the stomach by drops, and the more rapidly as the degree of its fluidity is greater. Food of difficult solution, remains a longer time in the stomach, and in some instances, even a week or more, and may then be vomited up unchanged, or pass off by stool. In general, the peristaltic action of the stomach continues, until the aliment is wholly dissolved by the gastric fluid, and has passed out of the stomach. The organ then resumes the state of contraction and quiescence, natural to it when empty. Fluids pass out

of the stomach very speedily, chiefly perhaps, by absorption.

Influence of innervation upon chymification.

That the par vagum or pneumo-gastric nerve exercises some important influence over digestion, has long been known to physiologists, though it is not yet fully ascertained what this influence is. The results of experimental researches on the uses of these nerves, by different physiologists have not been uniform; but sometimes directly contradictory. But it seems to be pretty generally agreed, that the division of these nerves in the neck, causes a suspension of the process of digestion.

Blainville passed a ligature round the nerve above the lungs, and the effect was a suspension of respiration and chymification. The ligature was afterwards withdrawn, and the two functions were restored. The same physiologist and Legallois, performed the experiment on pigeons; and it was found, that the corn swallowed by the birds, remained unaltered in the crop. Dupuy performed a similar experiment on horses. The animals ate and drank, but died on the sixth day; and on dissection no chyle was found in the lacteals. These experiments have been performed by several other physiologists, with similar results.

The functions which have been ascribed to the pneumogastric nerve, by different physiologists, in relation to gastric digestion, are of three kinds.

1. That it presides over the secretion of the gastric fluid.

2. That it animates the muscular motions of the stomach and œsophagus.

3. That it is the seat of sensation in the stomach, bestowing upon this organ both common sensibility, and the appetites of hunger and thirst.

The first opinion is adopted by Philip and Brodie, and, to a certain extent, by Tiedemann and Gmelin. Brodie found that in animals killed with arsenic,

after the section of the pneumogastric nerves, no trace of gastric fluid could be discovered in the stomach. Philip referred the suspension of digestion, after the division of these nerves in his experiments upon animals, to a suspension of the secretion of gastric fluid. Tiedemann and Gmelin ascribe the check which digestion experiences from the section of these nerves, to a paralysis of the muscular coat of the stomach; but they are also of opinion, that the secretion of the gastric fluid, and its acid qualities, are dependent on the influence of these nerves; and hence, that the division of them may retard digestion, by preventing the secretion of this fluid, as well as by paralysing the muscular fibres of the stomach. The formation of this acid secretion out of the blood, which is an alkaline fluid, they suppose, requires an energetic action of the nervous power on the blood, which penetrates into the capillary net work of the stomach; and they conjecture that this influence operates by causing a decomposition of the salts contained in the blood, viz.; the muriates of potash and soda, and the acetate of soda, the acids of which, they suppose, are secreted into the stomach, freed from their bases, and become integrant parts of the gastric fluid. This opinion is founded on an experiment, in which the stomach of a dog, in which both pneumogastric nerves had been divided with a loss of substance, and which had afterwards eaten the boiled white of eggs, exhibited no mark of acidity, its contents not reddening the tincture of turnsole. It seems probable, however, that the branches of the great sympathetic, which penetrate with the arteries into the coats of the stomach, have a very considerable, if not the principal share in the secretion of the gastric fluid.

2. Breschet inferred from his experiments, that digestion is retarded by the section of the par vagum, not in consequence of a suspension of the secretion of gastric fluid, but by a paralysis of the muscular fibres of the œsophagus and stomach, resulting from this operation; in consequence of which, the mechanical motions of the stomach, necessary to chymification,

are no longer executed, and the food lies motionless in the hollow sac. Breschet found that this operation retards, but does not destroy digestion.

Leuret and Laissaigne, also, performed the experiment on a horse, by cutting out a piece from the vagus, four or five inches long, on each side of the neck, and then performing tracheotomy, to prevent asphyxia, and then suffered the animal to eat. They found, however, that the œsophagus was paralysed by the operation, and the food forced back into it, and vomited up. To prevent this, they tied the œsophagus, and eight hours after the animal had eaten, it was killed; and they found that digestion had taken place, and the food was completely chymified. The experiment was afterwards repeated, with the same results; and the conclusion which Leuret and Laissaigne drew from it was, that digestion may take place independently of the par vagum. In fact, the vagus spends most of its inferior branches upon the œsophagus, sending but few to the stomach, which is supplied with nerves from the ganglionic system; and hence, the section of the vagus only *retards* digestion, which is still carried on under the influence of the great sympathetic.

It is a curious fact, that the influence of the pneumogastric nerves on digestion, may be supplied by galvanism and electricity, and even by mechanical irritation. If the nerve be merely divided, and the ends be suffered to remain in contact with each other, digestion is not suspended. The two ends must be removed from each other, or a piece cut out, to insure the effect; and in that case, if the inferior or gastric end of the divided nerve, be stimulated by a galvanic current, or even by mechanical irritation, digestion recommences. From this fact, Breschet inferred that electricity operates in restoring digestion, by exciting the muscular movements of the walls of the stomach, by means of which, the food is brought successively into contact with all parts of its inner surface; and that mechanical irritation operates on the same principle. This view is strikingly corroborated by a

fact, mentioned by Tiedemann and Gmelin; viz. that they had frequently witnessed, in experiments, that mechanical and chemical irritations, applied to the pneumogastric nerves, occasioned contractions in the muscular coats of the stomach.

3. Experiments make it probable, that the stomach derives cerebral sensibility from the par vagum; and that the sense of hunger, also, depends on the influence of these nerves.* Bell states, that animals killed by acrid poisons die without pain, if the par vagum are divided, but howling with agony, if these nerves are left uninjured. The section, or the compression by ligature, of these nerves, a little above the stomach, appears wholly to destroy the feeling of hunger. It is true that Leuret and Laissaigne cut out two inches of the par vagum in horses, and the animals continued to eat as before; from which these physiologists inferred, that the appetite was not affected by the division of these nerves. It was remarkable, however, that they continued to eat after the stomach was very much distended with food, a fact which makes it probable that the feeling of satiety was destroyed by the experiment, and the animals continued to eat automatically, as it were, without being prompted by appetite, to begin, or by the gratification of it, to leave off. The feeling of thirst, also, appears to be destroyed, as well as that of hunger and the appetite of respiration. The subjects of these experiments, probably, not only eat, but drink also, and respire automatically.

It is here proper to mention the assertion of Magendie, that if the section of the pneumogastric nerves be made in the thorax, below the place where the branches, which supply the lungs, are given off, the food, which is afterwards taken, is regularly converted into chyme, and furnishes abundant chyle; and he is disposed to attribute the suspension of digestion, when the nerves are divided in the neck, to the influence of

* Secetur nervous pneumogastricus. Cessat illico fames; non cessat illico digestio. *Martinius Element. Physiol.*

disturbed respiration upon the action of the stomach. Brachet, however, regards Magendie's experiments inconclusive, on account of the great difficulty of making a complete division of the pneumogastric nerves below the origin of the pulmonary branches, without dividing the œsophagus itself. In his experiments to determine this point, he found that, if the complete section of the par vagum was effected by the division of the œsophagus a little above the cardia, the stomach of the animal remained distended with the food taken just before the experiment; a very slight alteration only being perceptible in the contents of the stomach, several hours after the section of the œsophagus.

On the whole, it appears to be established by experiment, that the pneumogastric nerves not only give activity to the muscular fibres of the stomach and œsophagus, but also bestow cerebral sensibility upon the organ, and are the immediate seat of the sensations of hunger and thirst. It is probable, also, that the secretions of the stomach are influenced by the state of its sensibility, and that the section of these nerves, by impairing or destroying this power, may indirectly occasion a change in the qualities of the gastric fluid, or a diminished secretion of it, and in this manner, likewise, impair or suspend chymification.

It appears, also, that digestion is suspended by other operations, by which the nervous power is weakened. Wilson found that chymification was arrested by a section of the spinal cord, in the lumbar region; and Edwards and Vavasseur witnessed the same effect, from the removal of part of the cerebral hemispheres. An injection of opium into the veins, was found to produce the same effect.

According to Brachet, the *par vagum* is the channel, which transmits the impressions of medicinal and poisonous substances from the stomach to the brain. If a narcotic be administered in a sufficient dose, its effect upon the brain is perceived almost immediately, and long before the poison could be digested and ab-

sorbed. But, if the par vagum be previously divided, the effect is prevented. Brachet gave to each of two dogs six grains of opium, having in one previously divided the par vagum. The dog which had not undergone the operation, fell into a state of profound narcotism, while the other lay down quietly, and manifested no other symptom than the dyspnœa, which always results from the section of the pneumogastric nerves. The nux vomica, in like manner, which acts so violently and rapidly as a poison on dogs, produces no such effect if the par vagum be divided. The poison may be given in a double or triple dose, and yet *intoxication* will not be produced at once, as is commonly the case; but will manifest itself at a much later period, with much less intensity than common. Emetics and purgatives, also, administered to dogs which have suffered the division of these nerves, produce none of their usual effects. The poisonous effects of alcohol are first communicated to the brain through the same channel.

IV. *Chylosis.* The duodenum receives the chyme from the stomach, and has generally been believed to accomplish the second digestion, or the conversion of chyme into *chyle.* This intestine, like the other parts of the intestinal canal, is composed of three tunics, viz. a serous or peritoneal, a muscular, and a mucous. The first, however, covers only the anterior part of the intestine, and can hardly be considered as essential to it. The second, or muscular, is formed almost wholly of circular fibres. The third, or mucous, exhibits a great number of transverse folds, termed the *valvulæ conniventes.* It exercises a double secretion, one follicular, or mucous, the other perspiratory, or exhaling. The arteries of the duodenum are derived from the right *gastro-epiploic,* and the *splenic;* its nerves, almost wholly from the solar plexus. The situation of the duodenum is deep in the abdomen, on a level with the third or fourth lumbar vertebra; having behind it the vertebral column, the aorta, and the vena cava inferior; before it, the

stomach, and transverse mesocolon; above, the liver; and below, the small intestines.

In the duodenum, the chyme is exposed to the action of three new agents, by which its nutritious parts are further elaborated, and the constituent principles of chyle are developed. These agents are the intestinal fluid, the bile and the pancreatic secretion. The irritation, excited by the acid chyme on the inner surface of the duodenum, occasions a copious afflux of these fluids into the intestine. According to Tiedemann and Gmelin, the gall bladder is always empty during digestion, but full during fasting. The pancreatic fluid is secreted in increased abundance; and the stimulus of these two fluids, particularly of the acrid bile, in addition to that of the chyme, produces an increased secretion of the intestinal fluids, both the mucous or follicular, and the aqueous or perspiratory.

The intestinal fluid of the duodenum has some resemblance to the gastric liquor. According to Tiedemann and Gmelin, it is acid in the duodenum and the superior part of the small intestines, though less so than the gastric fluid; and it becomes gradually less and less acid, until at last, in the inferior part of the small intestines, its acidity disappears, and it becomes neutral. The free acid contained in the intestinal fluid is, chiefly, the acetic; the hydrochloric, which exists in the gastric fluid, being rarely present in the intestinal. The quantity of the intestinal liquor is said to be in proportion to the degree of indigestibility of the food.

The bile is a viscid fluid, secreted by the liver, of a greenish brown color, extremely bitter taste, and possessed of alkaline properties. It will be more particularly described hereafter.

The pancreatic fluid is a whitish semi-transparent fluid, of a slightly saline taste, and coagulable by heat. It contains a large proportion of albumen and caseine; and, according to Tiedemann and Gmelin, a free acid.

The mixture of these fluids with the chyme in the duodenum, effected by the contraction of this intestine, soon occasions a sensible change in its appearance. After passing the mouth of the *ductus choledochus*, it loses the homogeneous appearance which it presented in the stomach, and becomes more or less deeply colored with yellow, its central portion presenting a deeper hue than the parts nearer the intestine. The external part adheres to the duodenum, so that its motion through the intestine is less rapid than that of the central portion. The sour smell and taste of the chyme gradually lessen and disappear; and, according to the experiments of Marcet and Prout, albumen, which is an essential part of the chyle, is copiously developed. This substance begins to appear a few inches from the pylorus, and disappears in the inferior portion of the small intestines.

According to Prout, if the food contained no albuminous matter, no albumen is developed in the stomach; but, immediately on the entrance of the chyme into the duodenum, and its mixture with the biliary and pancreatic secretions, albumen and other principles of chyle begin to appear. This albumen is supposed, by Tiedemann and Gmelin, to be derived partly from the pancreatic fluid, which contains a large proportion of this principle; but most of it, probably, is developed from the food itself, by the changes which it undergoes in the duodenum. The albumen and the other chylous principles, are absorbed by the lacteals; and, combined together, they constitute the chyle.

According to Tiedemann and Gmelin and some other physiologists, chyle is not formed in the duodenum; for, they assert, that it is impossible to extract a particle of this fluid from the contents of this intestine. If this be true, the office of the duodenum is more completely to animalize the chyme, and to develope these principles or materials, necessary to the formation of the chyle. Leuret and Laissaigne, how-

ever, assert that all the essential principles of chyle preëxist in the chyme. Albumen, which is the basis of the chyle, exists abundantly in the chyme of the duodenum; and particles of fibrin, also, they affirm, may be detected in it. If chyme be examined with the microscope, globules may be perceived in it, which exactly resemble the globules of fibrin which exist in the chyle. These globules are not present in the gastric juice, intestinal fluid, bile, or pancreatic secretion; and, consequently, can be derived only from the food. In what manner the acidity of the chyme diminishes, as it descends in the small intestines, is not fully determined. Many physiologists suppose, that it is neutralized by the soda of the bile. Leuret and Laissaigne remark, that in chylification the bile and the pancreatic fluid prevent the fermentation of the chyme, by neutralizing its acid principles, and that fat substances, which had not been completely converted into chyme, are dissolved by the bile, and rendered suitable for nutrition. Tiedemann and Gmelin, on the contrary, maintain that the bile is wholly incapable of dissolving fat.* They also suppose, that the soda of the bile unites with and neutralizes a part of the hydro-chloric and acetic acids of the chyme; and that the free acid, still remaining in the latter, precipitates the mucus of the bile in a state of coagulation, and with this, a great part of the coloring principles of the bile; as appears from the fact, that the mucus which is precipitated, is of a brown color. Besides this mucus, several other principles are precipitated from the bile, as cholesterine, margaric acid, and resin, which Tiedemann and Gmelin found in the insoluble contents of the small intestines, and which contribute to the formation of the feces. The German physiologists, as well as Leuret and Laissaigne, found that digestion and the formation of

* La bile n'est pas capable de dissoudre le plus petit atome de graisse. Elle ne peut, donc contribuer a sa résorption que d'une manière méchanique en la tenant en suspension, quand elle est tres divisée. *Tiedemann and Gmelin, Recherches, &c.*

chyle, continued after tying the ductus choledochus; from which they inferred, in opposition to Mr. Brodie, that the bile has no agency in chylification.

According to Beaumont, bile is seldom present in the stomach; but when fat or oily food has been used for some time, this fluid passes into the stomach and mingles with the gastric liquor.

The pancreatic fluid, which contains a large quantity of albumen, a substance resembling caseine, and another, which has the property of becoming red by the action of chlorine, Tiedemann and Gmelin suppose, contributes to the assimilation of the chyme, in the small intestines, by the admixture of its principles, which contain a large quantity of azote. That these principles contribute to the assimilation of the chyme in the small intestines, appears probable from the fact, that they progressively decrease, as the contents of the intestines proceed in their course, being, undoubtedly, absorbed with the assimilated part of the aliment. Thus, according to Tiedemann and Gmelin, the contents of the small intestines contain a constantly decreasing proportion of albumen, of caseous matter, and of the peculiar substance, which becomes red by the action of chlorine, in their progress through this portion of the intestinal canal. The office of the pancreatic fluid, in animalizing the food, the German physiologists, also, infer from the greater comparative size of the pancreas in animals which live on vegetables, than in such as feed on animal matter. The wild cat, which is wholly carnivorous, has a much smaller pancreas than the domestic cat, which lives partly on vegetable food, though the latter is a much smaller animal.

The uses of the intestinal fluid are various. It probably completes the solution of those parts of the aliment, which were imperfectly dissolved by the gastric fluid. It also dilutes the chyme, and facilitates its progress through the intestinal canal, and lubricates the inner surface of the tube. Tiedemann and Gmelin, also, suppose that it serves as a medium by

which the chyme is united with the bile and pancreatic fluid.

The analysis of the contents of the small intestines, furnished Tiedemann and Gmelin with the following ingredients, viz.—

1. A *free acid*, the acetic, and sometimes the butyric. This is, perhaps, derived chiefly from the gastric fluid.

2. *Albumen.* This principle, as already observed, is found in considerable abundance in the duodenum, and gradually diminishes in the inferior portion of the small intestines. The albumen, Prout supposed to be formed out of the chyme only, in the duodenum, by the agency of the bile and the pancreatic fluid; for, he says, he never observed any trace of it in the chyme, or the aliments dissolved by the gastric fluid. Tiedemann and Gmelin, however, observe, that when the food consists of liquid white of eggs, or when it contains albumen, this principle is dissolved by the gastric fluid, and passes into the duodenum with the chyme, unchanged. Not only liquid white of eggs, but flesh, glue, and bread made of spelt, bones in dogs, and oats in horses, furnished an abundance of albumen; while fibrin, boiled white of eggs, gluten, milk and cheese, furnished but little. As the pancreatic fluid contains a great quantity of albumen, it is also probable, that this principle in the contents of the small intestines, is derived partly from the former. It is gradually absorbed by the lymphatics of the small intestines, and forms the basis of the chyle.

3. *Caseine.* Tiedemann and Gmelin almost always found in the filtered fluid of the small intestines, a matter, which was precipitated by distilled vinegar and the other acids, and which resembled caseine. This matter they suppose to be produced, partly by the secretion of the intestinal canal, and partly to be derived from the pancreatic fluid, which contains a matter resembling it. They suppose it to exercise an important part in the assimilation of alimentary

substances, and in their conversion into animal matter by imparting azote. It is a more highly azotized principle than albumen, and is absorbed by the lacteals.

4. A matter precipitated by chloruret of tin, and composed chiefly of ozmazome and saliva. This also is absorbed.

5. A substance, which becomes colored of a rose or peach-flower red, by chlorine, is almost always found in the small intestines. An excess of chlorine destroys the color. It was found in dogs, horses and sheep, in the duodenum, and the small intestines. Tiedemann and Gmelin suppose, that it is derived from the pancreatic fluid, in which it exists. It is never found in the stomach; but the ligature of the biliary ducts does not prevent its appearance. Consequently it is not derived from the bile. It is absorbed and perhaps contributes to the assimilation of the food.

6. Besides the foregoing, several substances were extracted by alcohol, which were insoluble in water, as fat, stearine, the coloring principle and the resin of bile, and cholesterine.

7 & 8. Carbonate of ammonia, and alcaline carbonates, phosphates and sulphates; with carbonate and phosphate of lime. On the whole, upon considering the changes which the food undergoes in the stomach and intestines, so far as they can be traced, it appears that its conversion into albuminous matter, which forms the basis of chyle and blood, is the great business of digestion. It is true, that no albumen is developed in gastric digestion; for, none can be detected in the chyme, except when the food consists of albuminous matter. But albumen is formed abundantly in the duodenum, and diminishes rapidly in the inferior parts of the small intestines, in consequence of its being absorbed by the lacteals; and Dr. Prout is of opinion, that the change, which the aliment undergoes in the stomach, consists in an approach to the nature of albumen, though none of this principle

can be discovered in the chyme of the stomach, when it has not existed in the food.

Motions of the small intestines.—During digestion, the peristaltic motions of the intestinal canal are performed with energy. These motions consist in alternate contractions and relaxations of the muscular fibres. The passage of the chyme through the duodenum, however, is slow; a fact which is owing to several causes, for instance, as the deficiency of the peritoneal coat, admitting of an easier dilatation of this intestine; its greater dimensions than those of the other small intestines; the weakness of its longitudinal fibres, and its various curvatures; and finally, the great number of its valvulæ conniventes, or transverse folds of its mucous membrane.

According to Brachet, the motions of the duodenum, like those of the stomach, depend on the influence of the pneumo-gastric nerves; for, the section of these nerves a few hours after taking food, paralyzes the duodenum and the superior part of the small intestines, in consequence of which the alimentary mass is arrested in its progress. The influence of the par vagum, however, does not extend through the whole of the small intestines; for, the inferior part has been found to empty itself of alimentary matter injected into it after the section of these nerves, while the aliment, injected at the same time into the superior parts, has been found partially digested, in the same places. The inferior part of the small intestines, appears to be under the influence of the spinal marrow, for the section of this medullary cord in the lower part of the back, arrests the progress of the chyme, suffering it to accumulate in the lower part of the small intestines, and in the large intestines. It appears then according to Brachet, that the muscular coat of the small, receives the nervous influence which stimulates it, from the cerebro-spinal system; and that, in respect to its power of contraction, it is under the influence of this system.

V. *Absorption.*—The contents of the small intestines, consisting of a mixture of chyme, the mucus of the intestines, and the intestinal liquor, of bile and pancreatic fluid, become more and more consistent, as they advance further in the canal by the contraction of its muscular tunic. The fluid parts are imbibed by numerous lymphatic vessels, originating in its mucous membrane, and conveyed under the form of chyle, into the thoracic duct, and thence into the torrent of the venous blood near the heart. The subject of absorption, will be considered hereafter. The intestinal mucus rendered more consistent, and combined with the insoluble and indigestible parts of the food, and with the fat, the resin, the coloring matter and mucus of the bile, form the incipient excrementitious mass, first assumes a distinct character in the last third of the small intestines. They arrive at length, by degrees, at the cæcum, where they remain some time, and where, as Tiedemann and Gmelin think, a last effort is made by nature to extract from the undissolved parts of the aliment, whatever they may contain, capable of affording nourishment. Before considering further, the functions of this part of the alimentary canal, it may be proper to describe the result of duodenal digestion, the nutritious fluid called chyle, though it is asserted by several physiologists, that this fluid does not exist in the intestines, but that it is formed by the action of the absorbent vessels, exercised upon the nutritious principles developed by the second digestion.

Chyle is the fluid contained in the lacteals. It is absorbed by these vessels from the aliment, after it has been digested in the stomach and duodenum, and is destined to the renovation of the blood. It is a fluid of a milk white color; but it varies in its consistence and appearance in different classes of animals, and according to the qualities of the food, and the quantity of the drinks. In carnivorous animals it is opaque; in herbivorous, transparent and of a greenish color; in birds and fishes, thin, serous, and transparent. It is said to have a spermatic odor, and a

sweetish or saltish taste, wholly unlike that of the aliments from which it is formed. Its specific gravity is superior to that of water, but less than that of blood. According to Tiedemann and Gmelin, and Magendie, it is alcaline.

In its chemical composition it has a strong analogy with blood. If left to itself, it coagulates, and separates into three parts, viz: a fluid, a coagulum, and a peculiar fatty substance. The first is an albuminous fluid, like the serum of the blood, and coagulable by fire, alcohol, and acids, contains the same salt in solution, and differs from the serum of the blood only in containing a peculiar fatty matter. The coagulum, like that of the blood, is formed of fibrin and a coloring matter. This latter substance, however, is white, instead of being red. The coagulum also contains a peculiar fatty matter not found in the blood. According to Bauer, Dumas and Prevost, chyle exhibits, under the microscope, the same globules as the blood, with the only difference that the globules are not surrounded with a colored envelope. Lauret and Laissaigne affirm that among all animals, whatever their food may consist of, the chyle contains fibrin, albumen, and a fat matter, muriate of soda, and phosphat of lime, in variable proportions. They also observe that the fibrin is not in proportion to the azote contained in the food; and that the chyle of animals, fed upon gum and sugar, contains as much fibrin, as that of those, which are nourished exclusively upon meat. The same, they affirm, is true respecting the albumen contained in the serous part of the chyle. Magendie, on the contrary, asserts that chyle formed from flesh, contains more fibrin; that from sugar, comparatively little; while that which is produced from oil, contains more of the fatty matter. According to Marcet, chyle produced from vegetable aliments, contains three times as much carbon as that formed out of animal substances; this last is always milky, and its coagulum opaque, and rose-colored, and covered with a layer of cream-like fluid; while vegetable chyle is destitute of this principle, is transparent, and has a

colorless coagulum. Tiedemann and Gmelin affirm, that chyle does not coagulate before it has passed through the mesenteric ganglions, and are of opinion from this fact, that the fibrin in the chyle, is not derived immediately from the food. The white color of the chyle is attributed by some physiologists to the fatty matter present in it. Lauret and Laissaigne, found the chyle milky and opake, from the presence of this matter, in the absorbent; but limpid, colorless, and destitute of fat, in the thoracic duct. In the thoracic duct in dogs, it has been observed of a reddish color, owing, according to Tiedemann and Gmelin, to the mixture of some of the coloring matter of the blood with it. In its passage from the intestines through the absorbent system, the chyle evidently undergoes considerable changes in its sensible and other properties, and probably becomes more completely assimilated and animalized. Lauret and Laissaigne say, that it is clearer and more aqueous, as it issues from the ganglions. Vauquelin observes, that it assumes a rose color in its progress in the lymphatic system, and Tiedemann and Gmelin, Emmert and Reuss assert, that it presents, in its exit from the mesenteric glands, a redder color, contains more fibrin, and is more coagulable, sometimes depositing a scarlet-colored cruor; changes which are ascribed, with apparent reason, to the action of the mesenteric glands. It is said to become red by exposure to oxygen or even atmospheric air. Out of the body it putrifies in a few days, if formed out of animal food; but vegetable chyle, it is said, will resist putrefactive decomposition several weeks. The analogy of chyle with the blood, in its composition and properties, is evident, from the history of the fluid, and it may properly be considered as blood in a rudimentary state.

Functions of the Cæcum.—This intestine is considered, by Tiedemann and Gmelin, as a reservoir, having some analogy with the stomach, especially in animals which feed on coarse vegetable matter, as ruminating animals, horses, the rodentes, and the pachydermis, in which this intestine has a large capacity, while in

the carnivorous animals, as cats and dogs, it is small, and is entirely wanting in those animals, which feed on fruits and the sweet roots of plants, as the bear and the badger. The large and numerous glands of this intestine secrete an acid fluid, which mixes with and dissolves the remains of the undigested aliment, that continues some time in the cœcum. This secretion also contains a little albumen, which is found in greatest abundance in animals which feed on vegetable matter. This albumine is supposed, by Tiedemann and Gmelin, to contribute to the assimilation of the aliments dissolved by the acid secretion. In this intestine, also, first appears the excrementitious matter of the intestines, under the form of a soft brownish or yellowish-brown paste, with the peculiar feculent odor, which Tiedemann and Gmelin suppose, is derived from a volatile oil, secreted principally by the cœcum. This view of the functions of the cœcum, however, is not entertained by other physiologists, though it is in this intestine that a feculent character first appears in the contents of the alimentary canal.

Defecation.—The passage of the feces through the large intestines is slow, but varies according to a variety of circumstances, from ten, twenty, or twenty-four hours, to several days. In some instances, substances have remained several months, in the cells of the colon. During its sojourn in the large intestines, the feculent mass becomes more consistent by the absorption of its thinner parts; its saline principles increase; the resinous and coloring matter, derived from the bile, become more concentrated, and impart a more stimulant quality to the mass. The fact, that the body may be nourished and supported, for a considerable time, by nutritive injections, appears to prove, not only that active absorption is exercised by the large intestines, but also, either that a sort of digestion is performed by this portion of the alimentary canal, or that the absorbent vessels of the rectum and colon, exert an assimilating power upon the crude aliment absorbed by them. In the rectum the feces become more dense, by the absorption of their aqueous part,

and assume the shape, under which they are excreted.

The large intestines differ from the small in the disposition of their muscular fibres; the longitudinal ones, being disposed in three bands, and shorter than the intestine, so that they pucker it up, forming numerous pouches or cells. The mucous membrane presents no trace of valvulæ conniventes, but is furnished with a great number of mucous follicles. Its nerves are derived from the hypogastric and lumbar plexuses, and its arteries, from the superior and inferior mesenteric. The contractions of the muscular fibres of the large intestine, are wholly without the domain of the will. But, in defecation, or the expulsion of the feces from the rectum, several accessory muscles are employed, which are under the control of this power, as the diaphragm above the ischio-coccygeal muscles, the levator ani, and the abdominal muscles. Astruc, and some others, supposed that defecation was performed exclusively by the efforts of the rectum; an error which called forth the witticism of Pitcairn—*Ast credo Astruccium nunquam cacasse.* The concurrence of the voluntary muscles with the action of the intestine itself, is indispensable to overcome the contraction of the sphincter of the rectum, particularly in the expulsion of feces of a hard consistence, which sometimes requires a strong effort of the will. The act is finally accomplished principally by a contraction of the abdominal muscles upon a full and sustained inspiration with the glottis closed, so that it is impossible to speak, during the expulsive effort.

According to Berzelius, feces afford the following ingredients, viz. water, 73.3; remains of animal and vegetable substances, 7.0; bile, 0.9; albumen, 0.9; extractive matter, 2.7; substances formed of altered bile, resin, animal matter, &c. 14; salts, 1.2. These salts are the carbonate, the muriate, and the sulphate of soda; ammoniaco-magnesian phosphate, and phosphate of lime.

The Liver.

This voluminous gland is one of the most important organs in the whole system, not only on account of its functions, but of its peculiar structure and circulation, and its sympathies with other important viscera.

It is found in all the vertebrated animals, and in the mollusca, in many of the crustacea, and the arachnides. In birds, reptiles, and fishes, its volume is greater in proportion to the size of the body, than in the human species, and the mammalia. In man, it is the most voluminous of the viscera, especially in the fetal state. It is situated in the right hypochondriac region, and the corresponding part of the epigastrium, having above it the *diaphragm*, to which it is connected by a fold of the peritoneum, called the suspensory ligament of the liver, below the right kidney, and the transverse colon and the stomach; behind the last dorsal vertebræ, and before the anterior part of the base of the chest.

Attached to the lower part of the liver, and partly imbedded in it, is a pyriform sac, called the gall-bladder, having its fundus, or larger extremity, placed forward, in a groove of the anterior border of the liver, and frequently projecting beyond it; and its neck and smaller extremity turned backwards and terminating in a canal, called the cystic duct. It is composed of two membranes or coats, viz. a cellular or muscular, as it is considered by some anatomists, and an interior mucous one. Besides these, it is partly covered by the peritoneum, by which it is attached, and the liver.

The color of the liver is a reddish brown; but in a diseased state it varies a good deal, becoming darker or lighter, according to the nature of the disease. In some cases, it becomes universally of a cream color. According to Rudolphi, the very dark color of the organ is connected with a softness of its texture, and with a dark-colored bile; and on the other hand, an unusually light color of its substance,

with a firmer texture, and a light-colored bile. The substance of the liver is formed of a glandular parenchyma, the granulations of which become apparent by lacerating its tissue.

The importance of the liver is manifest, from the immense supply of blood which it receives, and from the extraordinary distribution of its vessels. It differs from all the other glands in receiving a large supply of venous blood, in addition to the arterial blood which is sent to it, in common with all other parts of the body.

Its arterial blood it receives, principally, by a branch of the cælic artery, called the hepatic. It also receives some branches from the coronary artery of the stomach, and the inferior diaphragmatic arteries. Sometimes, a branch of the superior *mesenteric* is sent to the right lobe. Its venous blood is derived from the viscera of the abdomen; the veins of which, in their course to the liver, unite into a large trunk, called the *vena portæ*. On entering the liver, this great vein divides and subdivides into innumerable branches, in the manner of an artery, and is distributed to every part of the glands. The system of the vena portæ is a curious anomaly in the circulation, and was compared, by Galen, to a tree, whose roots were dispersed throughout the abdomen, and its branches in the liver. This organ thus possesses two distinct vascular systems, an arterial and a venous, a character in which it resembles the lungs. The extreme divisions of these two vessels, the hepatic artery and the vena portæ, terminate in the radicles of the hepatic veins, which gradually unite into large venous trunks, that enter the vena cava inferior, and convey the returning blood to the heart. From the extremities of these vessels, also, and communicating with them, spring the minute radicles of the biliary duct, called the pori biliarii, which secrete the bile from the blood; and, by their union in a large trunk, constitute the hepatic duct. Haller says, that the radicles of the biliary ducts communicate immediately with the last divisions of the vena portæ, a

structure from which he explains the passage of the bile into the blood in jaundice, when an obstacle in the hepatic duct prevents the passage of this fluid into the intestines.

The hepatic duct, which is formed by the union of all the excretory ducts of the liver, is a canal, about the size of a writing-quill, and an inch and a half in length. It is joined at a very acute angle, by the duct of the gall-bladder, called the cystic duct, and forms with it the ductus choledochus, a canal, eighteen or twenty lines long, which pierces the coats of the duodenum, and terminates on the inner surface of that intestine, three or four inches from the stomach. The gall-bladder is wanting in many animals. It has been absent in man, without any apparent injury to health.*

The ductus choledochus is wanting in many of the amphibiæ, in which the hepatic and cystic ducts open separately into the duodenum. In fishes, this duct arises immediately from the gall-bladder.

The nerves of the liver, which are few in number compared with its volume, are derived principally from the solar plexus, and follow the course and branchings of the hepatic artery. Some of its nerves, however, it derives from the pneumo-gastric. It is abundantly supplied with lymphatics; those that originate in the parenchyma of the organ, and contain a yellowish-colored lymph, the color being derived from an admixture of bile absorbed by them.

The great office of the liver, is the secretion of bile. In regard to this secretion, however, several questions have arisen, which have led to much controversy among physiologists. One relates to the source of this secretion; another, to the uses of it. With regard to the source of the bile, it has been a question with physiologists, whether this fluid is secreted out of venous or arterial blood; since the liver is supplied with both kinds, by the hepatic artery and the vena portæ. Some physiologists have contended,

* Le Pelletier.

that the hepatic artery supplies the materials from which the bile is secreted, from the analogy of the other secretions, which are all formed from arterial blood. To this, however, it is replied, that carbon is secreted in the lungs from the venous blood of the pulmonary artery, which ramifies through the lungs as the vena portæ branches in the liver; and, therefore, that it is possible that bile, which contains a large proportion of carbon, may also be secreted from venous blood. Comparative physiology, also, furnishes a reply to this argument, in the fact, that in some of the lower animals, as the reptiles, the urine is secreted, in a great measure, out of venous blood. Another argument is founded on the disproportion between the vast quantity of venous blood, which the liver receives, and the inconsiderable quantity of bile secreted by the organ. A disproportion, however, quite as great if not greater, exists between the vena portæ and the hepatic veins, which must, nevertheless, convey not only the residual blood of the vena portæ, but that of the hepatic artery, also, into the vena cava inferior. Besides, it is probable, and indeed certain, that a part of the bile secreted, is immediately absorbed by the lymphatics, and conveyed into the thoracic duct.

Mr. Abernethy describes a remarkable case, in which the vena portæ opened directly into the inferior vena cava. The hepatic artery was larger than usual. In this case, the bile found in the biliary ducts, must have been secreted from the blood of the hepatic artery. Lawrence describes a case, in which a similar anomaly existed. To this it may be added, that the vena portæ does not exist in the invertebrated animals; and yet these possess a liver, which secretes bile.

Infections pass from the hepatic artery into the biliary ducts, proving a direct anastomosis of the ultimate branches of the hepatic artery with the radicles of the biliary ducts.

Tying the hepatic artery, is said to cause a cessation of the secretion of bile. This, however, is incon-

clusive, because the liver is nourished by the arterial blood of this vessel; and if its nourishment is withheld from it, and the stimulus of arterial blood withdrawn, it is not surprising, that its secretory functions should be suspended. The fact, however, is denied, and needs confirmation. That the bile is secreted from the portal blood, is inferred, on the other hand, from the following considerations, viz.—

The vena portæ conveys a much larger quantity of blood into the liver, than the hepatic veins can carry out. The excess, it is reasonable to suppose, is employed in the formation of bile. If it be not so disposed of, it is difficult to imagine what becomes of it.

Injections pass very easily from the vena portæ into the biliary ducts. It is alleged, also, that the venous blood is more analogous to bile, in its constitution and properties, than arterial, as it contains more carbon and hydrogen, principles which abound in bile, but less azote; and is darker colored and more consistent. It has even been observed, that the portal blood possesses, in a greater or less degree, the qualities of bile.

Tying the vena portæ occasions a suspension of the secretion of bile.

According to Rudolphi, there is a free communication between all the blood-vessels of the liver, viz. the branches of the hepatic artery, those of the vena portæ, and of the hepatic veins, and the biliary ducts; from which he infers, that the principles out of which the bile is formed, are easily separated from the blood. He affirms, that he has seen colored water injected into the vena portæ, readily pass into the hepatic artery. Perhaps this free communication is an argument in favor of bile being secreted from both kinds of blood.

The excretory duct of the liver terminates in the duodenum, three or four inches from the pylorus. But before it arrives at this intestine, it is joined by the duct of the vesicula fellis. Of course, at this point, the bile from the liver can pass in one of two

directions, viz. either directly into the duodenum, or, by turning a very acute angle, into the gall-bladder. During digestion in the duodenum, when this intestine is stimulated by the presence of chyme, and is in a state of vital erection, the stimulus is communicated to the mouth of the common duct, and propagated, along both its branches, to the liver and gall-bladder; so that the hepatic and cystic bile are solicited, at the same time, to pass into the duodenum; and the gall-bladder and the hepatic duct both empty themselves of bile. But, when the duodenum is not engaged in the work of digestion, the hepatic bile is diverted into the other channel, and passes into the gall-bladder, where it remains until called for, and undergoes some change in its properties, becoming more concentrated, bitter and viscid, in consequence of the absorption of its aqueous parts by the lymphatics; and, probably, receiving some addition from the secretion of the mucous membrane of the gall-bladder. If it be retained a long time in the vesicula fellis, its bitterness becomes excessive, and its color of a deep green, by the great concentration of its peculiar principles.

Bile differs more from the blood than most of the other secreted fluids. It is a fluid of a greenish brown color, extremely bitter and viscid. It consists of water, albumen, resin, and soda, both free and united with the phosphoric, sulphuric and hydrochloric acids, and a yellow coloring matter. It derives its leading properties from a coloring fatty substance, called *cholesterine*, which forms the basis of biliary concretions; a resin, which gives the bile its bitterness; *albumen*, which causes it to froth on being agitated; free *soda*, to which it owes its alkaline properties; and various salts, composed chiefly of soda, combined with phosphoric, sulphuric and hydrochloric acids.

The secretion of bile appears to be unintermitting. It has been found in experiments, in which the orifice of the common duct was laid bare, that the bile issued

drop by drop, and gradually diffused itself over the intestine.

The lymphatics of the liver contain a lymph, colored with bile, which they convey into the thoracic duct. Berthold supposes that the bile, contained in this lymph, contributes to the assimilation of the chyle.

The uses of the bile have already been considered in part. It probably acts as a stimulant to the mucous and the muscular coats of the intestines, soliciting a flow of the intestinal fluids, and exciting the peristaltic contraction of the canal. Hence the unusual dryness of the feces, and the constipation of the bowels in jaundice, and in animals, in which the biliary duct has been tied. Tiedemann and Gmelin, also, suppose that it contributes to animalize those articles of food, which do not contain azote, by imparting to them its own principles, which are highly charged with azote; that it neutralizes a part of the acid contained in the chyme, which is derived from the gastric; and that it counteracts the putrefaction of the contents of the intestines, which they infer from the fact, that the feces are unusually fetid in dogs, in which the ductus choledochus has been tied.

But the German physiologists also view the bile as an important excretion, designed to maintain the blood in a state of composition necessary to qualify it for the nutrition, in the different organs. The reasons on which this opinion rests are briefly the following, viz.

1. Most of the constituent principles of the bile, as the resin, the coloring matter, the mucus, and the salts, concur to the formation of the feces, and are rejected from the system with the latter.

2. When the bile, by any cause, is prevented from passing into the intestinal canal, as in animals in which the biliary duct has been tied, or in persons affected with jaundice, the materials of the bile are separated from the blood by means of other secretory organs, particularly by the kidneys, but partly by the

serous and mucous membranes, and by the skin. The principles of this fluid are also deposited in the cellular tissue, in the coats of the arteries, veins, and lymphatics, and even in the dense fibrous tissues, the cartilages and bones, which all assume a yellow hue.

3. The liver appears to perform a function analogous to that of the lungs; since it separates from the venous blood a large quantity of carbon, in the form of resin, coloring matter, fatty matter, and mucus. In the lungs the excess of carbon, derived from the vegetable part of the food, is excreted in the form of a gas, and in a state of oxydation; but in the liver, it is thrown off in the form of a liquid, and in combination with hydrogen constituting the resin and fatty matter of the bile, and still in a combustible state. A fact favorable to the opinion, that the liver is auxiliary to the lungs, in decarbonizing the blood, is that the resin of the bile, which exists so largely in this fluid, and is excreted from the body with the feces, exist in the greatest proportion in herbivorous animals. Thus the bile of the ox contains much more of it, than human bile, or that of the dog; and Tiedemann and Gmelin infer, that this resin is derived chiefly from vegetable aliment. These physiologists also remark, that the lungs and liver, in different species of animals, are in a state of antagonism to each other. If the lungs are largely developed, if the system frees itself of a large quantity of oxydated combustible matter, by the respiratory organs, the liver is small, and the secretion of bile inconsiderable. But if the lungs are small, or imperfectly developed, the liver is large, and the biliary secretion, copious. Thus the liver is proportionally large in reptiles, which respire by means of lungs with large cells, like sacs or bladders, and whose pulmonary circulation is incomplete, and which decarbonizes the blood slowly. On the other hand, warm-blooded animals with well-developed lungs, as the mammalia and birds, which consume the largest proportion of oxygen, in a given time, and throw off the greatest quantity of carbonic acid, have the smallest livers in proportion to the size

of their bodies. In fishes, on the contrary, which live in the water, and breathe by means of gills, the liver is comparatively large. In these animals respiration is very imperfect, being maintained only by the small quantity of air, combined with the water in which they live, and being performed by gills, the structure of which is less favorable than that of the lungs, to the absorption of oxygen. The enormous size of the liver in the mollusca, which breathe by gills, or by small imperfectly developed lungs, tends to corroborate the same opinion. It is also worthy of remark, that the system of the vena portæ is more highly developed, and much more complicated in its structure in reptiles and fishes, than in the mammalia and birds. For, while this great venous trunk in the latter is formed only by the veins of the stomach and intestinal canal, the spleen and pancreas, in reptiles and fishes, it receives several other veins. Thus in tortoises, not only the veins of the spleen, and of the intestinal canal, but those of the posterior extremities, of the pelvis, of the tail, and even the azygos, unite with the vena portæ. In serpents this vein, also, receives the right renal vein, and the intercostals. In fishes the vena portæ receives the veins of the tail, of the kidneys and of the genital organs; so that the quantity of venous blood, which arrives at the liver, is proportionally much greater than in the other classes; and indeed the greater part of the venous blood traverses the liver and contributes to the secretion of the bile, before it arrives at the heart and the organs of respiration.

4. The great comparative size of the fetal liver furnishes another argument in favor of the view, that the bile is an excrementitious fluid. During the fetal state, the greater part of the blood which is brought from the placenta by the umbilical vein, arrives at the system of the vena portæ, and circulates in the liver before it is conveyed to the heart by the inferior vena cava. The bile also is secreted abundantly, as appears from the great quantity of meconium, which exists in the intestines in the later period of utero-

gestation. It is evident, that, in the fetus, the bile cannot be subservient to chylification; and the probability is, that the office of the liver in this stage of existence, is to purify the blood of the umbilical vein, from such organic principles as are injurious to the animal economy, and to maintain the composition of the blood in a state suitable for the nutrition of the body. It is probable, therefore, that, in the fetal state, the liver acts in part as a substitute for the lungs, which, after birth, perform the office of purifying the blood of noxious principles, by a kind of combustion with the oxygen of the air.

5. Another fact, which is relevant to the subject is, that the secretion of bile continues in the hybernating mammalia, the reptiles, and the mollusca, although these animals take no nourishment during the whole course of their winter sleep.

6. Tiedemann and Gmelin, also, adduce some pathological facts to corroborate their opinion. In general, they remark, the secretion of bile is augmented in derangements of respiration; and whenever an air is respired, which is vitiated by putrid animal or vegetable emanations.

The Pancreas.

This is a gland, five or six inches in length, of a whitish color, and lying transversely across the body of the twelfth dorsal vertebra, covered by the stomach, and almost circumscribed by the three curvatures of the duodenum. It receives numerous blood-vessels from the splenic, the right gastro-epiploic, the superior mesenteric, the coronary of the stomach, the hepatic and the inferior diaphragmatic. It derives its nerves from the ganglionic system, by the hepatic, the superior mesenteric, and the splenic plexuses.

This gland is of a granulated texture, consisting of small granules, or acini, united together by cellular membrane; these acini being aggregated into smaller, and these again into larger lobes. These lobes give origin to the fine pancreatic ducts, which unite to-

gether into one large excretory, called the duct of Wirsungius. This canal runs the whole length of the pancreas, and opens, by its larger extremity, into the duodenum, near the end of its second curvature, sometimes by a separate orifice, and sometimes by a common mouth, with the ductus choledochus. In some cases, its mouth has been found two inches distant from the orifice of this duct. Its passage through the coats of the intestine, is oblique, running under the mucous membrane in such a manner as to leave a free border of the latter, which exercises the functions of a valve. Sometimes there are two pancreatic ducts.

This gland is found in all the mammalia, in birds, and in the amphibia. It exists in some fishes, but, in others, it is wanting.

The pancreatic fluid is a white, or light yellowish, somewhat viscid fluid, inodorous and semi-transparent, and of a slightly saline taste. It becomes frothy by agitation, and coagulates by heat; and when it is putrefying, diffuses an ammoniacal odor. Physiologists have differed a good deal as to its constitution and properties. Some consider it as an acid, others as an alkaline fluid. Leuret and Laissaigne, and many other physiologists, consider it as very similar to saliva; while Tiedemann and Gmelin say, that it differs essentially from saliva, in containing a free acid, a large proportion of albumen and caseine, of which the saliva offers only slight traces; and, in the absence of mucus, of salivary matter, and of the sulphocyanate of potash.

The secretion of this fluid appears to be slow. Magendie exposed the orifice of the pancreatic duct in dogs, and wiped the mucous membrane of the intestine dry, with a piece of fine linen; and he observed that the pancreatic fluid issued only in drops, which scarcely appeared once in half an hour, and sometimes not so often. In birds, the quantity which issues is much greater. Leuret and Laissaigne obtained from the pancreatic duct of a horse, in half an hour, three ounces of fluid. Tiedemann and Gmelin

obtained from a large dog only about ten grammes, or one third of an ounce, in four hours. A drop issued out every six or seven seconds. When the animal made a deep inspiration, and the abdominal viscera were strongly compressed by the diaphragm, the discharge was more copious, sometimes several drops issuing in a second. Schuyl obtained two ounces in about three hours. It appears, from these experiments, that the quantity of this secretion varies much at different times, and probably under different circumstances. The stimulus of chyme in the duodenum, propagated from the mouth of the duct to the interior of the gland, gives rise to an increased flow of blood to it, and a more copious secretion of the pancreatic fluid. From the position of the gland, in relation to the stomach, it must be exposed to pressure whenever this organ is distended with food, and probably is stimulated by the pressure to increased secretion. This gland, as before remarked, is proportionally larger in herbivorous, than carnivorous animals; a fact, which seems to indicate its importance, in the assimilation of aliment of difficult digestion. It appears, however, that the pancreas may be extirpated in dogs without fatal consequences, or even serious injury to health. Brunner extirpated the gland in several dogs, and observed, a voracious appetite, and the most obstinate constipation, as the consequences.

Food.

The food of man is derived both from the animal and the vegetable kingdoms. Prout remarks, that organized beings adopt as aliments, substances lower than themselves in the scale of organization. Thus, plants and the lowest kinds of animals have the power of assimilating inorganic substances, such as water and carbonic acid. In ascending the zoological scale, we find that animals generally prey upon those which are inferior to themselves in organization, in magnitude or intelligence, until we arrive at man himself. "By this beautiful arrangement in the mode

of their nutrition," Prout remarks, "animals are exonerated from the toil of the initial assimilation of the materials composing their frame; as, in their food, the elements are already in the order which is adapted for their purpose. Hence, the assimilating organs do not require that complication, which otherwise they would have needed, and much elaborate organization is saved."

Animal food is more easily and speedily digested than vegetable, because it approaches much more nearly to the nature of the system it is destined to nourish. Probably every kind of animal matter is capable of being converted into nutriment. Food is derived from every department of animated nature, to supply the wants or to gratify the appetite of man. The mammiferous quadrupeds, birds, fishes, reptiles, insects, and the crustaceous and molluscous animals, are all greedily sought after and devoured by man.

Of the animal principles, those which contain the greatest proportion of azote are, perhaps, the most nutritious, as well as most stimulating. This is particularly true of fibrin, which forms the basis of muscular flesh, and is a constituent principle of the blood. It contains about twenty per cent. of azote, and is highly nutritious. The same is probably true of cheese, which the experiments of Sir A. Cooper would lead us to conclude is a substance of easy digestion, and is highly nutritious. It is highly azotized, containing about twenty-one per cent. of azote. Londe remarks, that, of all aliments, the fibrinous are those which remain the longest in the alimentary canal, which exact the greatest labor of digestion, excite the greatest animal heat in the stomach, stimulate the blood-vessels of the mucous membrane, and the general circulation, and cause the most copious secretion of the gastric and intestinal fluids. It is one of those which undergo the greatest alteration by digestion, and leave the smallest residue. When fibrinous aliment contains osmazome, it is, of all kinds of food, the most exciting, and the most nutritious.

Albumen is another animal principle, which is extremely nutritious, and of easy digestion. According to Tiedemann and Gmelin, the liquid white of eggs is dissolved by the gastric liquor, and passes into the duodenum, without undergoing any sensible change. It is coagulated, however, by the gastric fluid, before it is dissolved. Albumen exists in the blood, in the matter of the brain and nerves, and in other forms of animal matter. Caseine appears to be a modification of albumen; and the white of eggs consists of this principle. It contains about fifteen per cent. of azote. Albumen, if uncoagulated, is rapidly digested, and excites but little heat. Aliments containing it, pass out of the stomach so much the more speedily, as they have been less altered by cookery. It is very nutritious, and leaves but little residue.

Gelatin is a highly nutritious principle. It is extracted from the tendinous, and ligamentous, and cartilaginous parts of animals; and constitutes the basis of soups. It is found in none of the animal fluids. The flesh of young animals contains more gelatin, but less fibrin than that of old ones. Gelatin excites so little the local action of the stomach, that, according to Londe, it requires the aid of stimulants in order to be digested. It passes rapidly through the alimentary canal, and, by some authors, is considered as laxative. It produces little or no excitation of animal heat, or of the circulation—and leaves little residue.

Osmazome, according to Orfila, is stimulating, but possesses no nutritious properties.

Animal fat and oils. These principles are very nutritious, and are wholly convertible into chyme; but, if separated from other animal principles, are not very digestible. But, as they exist interspersed between the fibrinous parts of animals, they render the latter more tender and easy of digestion. Even the substance of the *bones* cannot resist the powers of digestion. The spongy bones are more easily digestible than the hard; but they all contain gelatin, and many of them oil or marrow; both of which are very nutritious. The vegetable principles, which afford

nourishment, by being converted into chyme, are starch, mucilage, sugar, oil and fats, and gluten.

Starch is found in a variety of vegetables, particularly in several of the nutritious grains, as wheat, oats, barley, rye; and it constitutes most of the nutritious part of rice, barley, and maize; it exists also, largely in potatoes. Sago, tapioca, salep, and arrow-root, consist almost wholly of starch. It is a curious fact, that, as soon as starch is dissolved by the gastric fluid, it loses the property of assuming a blue color by the action of iodine. Londe asserts, that aliments, in which starch predominates, pass more speedily through the stomach, than those in which fibrin, albumen or gelatin, abounds. The digestion of the amylaceous aliments produces but little elevation of heat, and no sensible acceleration of the pulse. Of all vegetable aliments, they are the most nutritious.

Mucilage abounds in many of the garden plants, as carrots, beets, turnips, cabbages, lettuce, melons, &c., combined in some of them with sugar, &c., and with woody fibre. The various gums, as, for example, gum arabic, consist of some modification of mucilage, in a solid form. Wherever it exists, it is nutritious. Mucilaginous aliments excite little or no heat, or increased activity of the circulation; on the contrary, they produce a general relaxation of the tissues, and diminish the energy of all the functions. Gum is extensively used as an aliment, by the Moors of Lybia and Senegal.

Sugar abounds in the saccharine fruits, as grapes, raisins, figs, dates, the sugar-cane; pears, apples, peaches, berries, &c. In these last, it is combined with the malic acid. It also exists largely in the beet, the parsnip, the sap of the maple and of the ash. It is very nutritious; but, according to Magendie, though it is easily digested, and leaves no residue, it is incapable of furnishing a chyle, which can support life more than thirty or forty days. From the experiments of Magendie, it appears that an exclusive use of sugar produces ulcerations of the cornea.

Oil exists in the cocoa, chocolate, olives, almonds, and other nuts. It is very nutritious, being wholly convertible into chyme; but is not very easy of digestion.

But the most nutritious of the vegetable principles is *gluten.* This differs from the other proximate elements of vegetable matter, in approaching pretty nearly to the constitution of animal matter, especially in containing a considerable proportion of azote. It is the most highly animalized of vegetable principles. It exists in the farinaceous grains, particularly in wheat, in which it is very abundant; and on the presence of this principle depends the property in wheat of undergoing the *panary* fermentation, or of making bread. Wheat flour makes the best bread, from its containing more of this principle than any other grain. Substances destitute of gluten, as rice, maize, barley, are incapable of the panary fermentation, and of making good bread. It is highly nutritious.

Gluten is found, though sparingly, in various parts of the vegetable kingdom; as in certain flowers, fruits, the leaves of certain plants, cabbages, and some roots. Combined with starch, it is extremely nutritious.

Dr. Prout has reduced the various nutritious principles of animal and vegetable matter, under three general heads, viz. the *saccharine*, the *oleaginous*, and the *albuminous.* The first, or the *saccharine*, comprehends *sugar*, *starch*, *gums*, *acetic acid*, and some other analogous principles; the second, or the *oleaginous*, *oils*, *fats*, *alcohol*, &c.; the third, or the *albuminous*, other animal substances, particularly *albumen*, *fibrin*, and *gelatin;* and the vegetable principle, *gluten.**

The *saccharine group* embraces two classes of substances, viz. the crystalizable and the uncrystalizable. The crystalizable are sugar, and the acetic acid. Sugar is a triple compound of hydrogen, oxygen and carbon. But it is worthy of remark, that the hydrogen and oxygen are combined exactly in

* Prout.

the proportion in which they form water; from which it is inferred, that sugar is a compound of water and carbon, or is a *hydrate* of carbon. Vinegar is another proximate principle which is crystalizable; and, like sugar, is formed of carbon and water, though the proportions of the carbon and water are different from those that form sugar. They differ, however, in the circumstance, that we can form vinegar artificially, but not sugar.

The uncrystalizable substances belonging to the saccharine group, are starch and *lignin*, or woody fibre. The former of these, or starch, in its composition, very nearly coincides with sugar; i. e. it is composed of water and carbon, and the proportions in which they are combined are very nearly the same as in sugar.

The second, or *lignin*, in all its varieties, has been found to possess very nearly the same essential composition. It is a hydrate of carbon, consisting of equal weights of this principle and water. The affinity of these four substances appears not only from their similarity of composition, but from the fact that they are convertible into one another. Thus, both starch and wood may, by artificial processes, be converted either into sugar or into vinegar: wood may also be converted into a kind of starch; and sugar into vinegar; though we cannot reverse the process, and convert vinegar into sugar, or starch into wood.

The *oily group*, in all their varieties, are all essentially the same in their composition, being composed of olefiant gas and water. Alcohol is referred to the same group by Prout, as its composition is the same.

The *albuminous group* comprehends albumen, gelatin and fibrin, of which the animal tissues are chiefly composed, and caseine, or the curd of milk. The vegetable principle, gluten, is referred, by Prout, to the same class. All of the albuminous group differ from the saccharine and the oleaginous, in containing

a fourth principle, viz. azote. One of them, viz. gelatin, is easily convertible into a kind of sugar.

"Such," says Prout, "are the three great staminal principles, from which all organized beings are essentially constituted"—"and, as all the more perfect organized beings feed on other organized beings, their food must necessarily consist of one or more of the above three staminal principles. Hence, it not only follows, as before observed, that, in the more perfect animals, all the antecedent labor of preparing these compounds *de novo*, is avoided; but that a diet, to be complete, must contain more or less of all the three staminal principles. Such, at least, must be the diet of the higher classes of animals, and especially of man."

This view of the nature of aliments, Prout remarks further, is illustrated and confirmed by the composition of milk; the only substance expressly designed and prepared by nature as food; and in which, therefore, we should expect to find the model and prototype of nutritious matter in general. Now, every sort of milk, Prout remarks, is a mixture of the three staminal principles above described; for, milk always contains a *saccharine;* a *butyzaceous*, or *oily;* and a *caseous*, or *albuminous* principle.

These views of Prout receive some confirmation from certain experiments of Magendie, on the effects of particular kinds of diet in animals. A dog was fed exclusively upon white sugar and water, and, for seven or eight days, he appeared to thrive upon this diet. In the second week he began to lose flesh, though his appetite continued good. In the third, he lost his spirits, and his appetite failed; and an ulcer formed on the middle of each cornea, which penetrated into the chamber of the eye, and the humors of the eye, escaped. The dog died at the thirty-second day of the experiment. Similar results ensued with dogs fed on olive oil and distilled water, except that ulceration of the cornea did not take place. Another dog, fed upon white bread, made of pure wheat, and with water, died at the expiration of fifty days. An

ass fed upon boiled rice, lost his appetite, and died in fifteen days.

On the whole, it appears to be established by experiment, that a certain variety in the food is necessary to the health of man, and of other animals. The experiments of Dr. Stark, upon the effects of various simple kinds of food, when used exclusively for a considerable time, appear to prove, that the system is reduced to a state of great debility and emaciation by such a course of diet; and that there is not a single article of food, however nutritious, capable, of itself, of supporting the vigor of the system.

CHAPTER XVII.

Absorption.

After the chyme has been subjected to the second digestion in the duodenum, its nutritious parts are absorbed and carried into the circulation, and, almost immediately afterwards, are subjected to respiration in the lungs, where their conversion into blood is completed. The route, which the chyle takes in its passage from the intestines to the circulation, is through a part of the absorbent system; and the functions of this system, or the physiology of absorption, is next to be considered.

The absorbent system consists of the *lymphatic vessels*, the *conglobate glands*, and the *thoracic duct*.

The lymphatics are fine pellucid vessels, which exist in all parts of the body, and terminate in the venous system, into which they convey the fluids which they absorb. The lymphatics consist of two coats, of which the external is cellular, and capable

of considerable extension; while the internal, like the inner coat of the blood-vessels, is smooth, and possessed of little extensibility, and forms numerous folds or valves, which, in general, are arranged in pairs. These valves are disposed in such a manner, with their bases directed towards the origins of the vessels, and their free margins towards the heart, as to permit the free passage of their contents toward the veins, but to prevent it in the opposite direction.

The lymphatics are endued with considerable irritability, which continues several hours after death. If an animal be killed, about the close of the process of digestion, upon opening the abdomen, the lacteals will be found turgid with chyle. But these vessels, irritated by the contact of the air, gradually contract; and, in the course of a minute or two, wholly disappear. A similar result may be obtained within the space of twenty hours after death. But, after this time, the irritability of these vessels is annihilated, and they continue distended with chyle, notwithstanding the contact of the air. If the thoracic duct, or any other lymphatic trunk, be tied in a living animal, and a puncture be made in the vessel below the ligature, the lymph spurts out in a jet; but, if the experiment be performed some time after death, the fluid escapes from the vessel slowly.

The lymphatics are very elastic and possessed of great powers of resistance. A lymphatic, which is so fine as to be scarcely perceptible when empty, may acquire a diameter of half a line, when distended by an injection; and, if again emptied, it will resume its original dimensions. Their powers of resistance are much superior to those of blood-vessels of the same diameter.

The lymphatics originate in two sources, viz. the surfaces of all the membranes, and the parenchyma, or internal tissue of all the organs. Thus, they originate, 1. from the areola of the cellular tissue, throughout its whole extent; 2. from the serous membranes, as the peritoneum, the pleura, the pericardium, the cavities of the joints, and, perhaps, those

of the brain; 3. from all the mucous membranes, as the inner surface of the organs of respiration and digestion, and of the sexual and urinary organs. To this branch of the lymphatic system the lacteals may be referred, as they spring from the mucous membrane of the digestive canal; 4. from the outer skin. They originate, also, from the tissues of all the organs themselves, as the muscles, the glands, bones, &c. Hence, it appears that all parts of the organism, with the exception of the hair, the nails, the epidermis, and the enamel of the teeth, are furnished with these vessels. They have not been detected, however, it is said, in the brain, the spinal marrow, the eye, and the internal ear; though, according to Rudolphi, Mascagni and Schreger saw lymphatics in some parts of the eye; and he affirms, that they have often been seen in the brain. It is a disputed point among physiologists, whether the absorbent vessels originate by open mouths or not. Some suppose that they commence in small spongy masses; others, that they originate in erectile ampullæ; others, in vesicles susceptible of transudation. But Bichat and some others think that they commence by small absorbing mouths, like those of the *puncta lachrymalia*.

In the limbs, the lymphatics form two sets, viz. a superficial, and a deep-seated. The former is situated in the cellular tissue, beneath the skin, and accompanies the subcutaneous veins; the latter is found, principally, in the intermuscular spaces, round the nerves, and the great vessels. Both sets ascend from their origins towards the upper parts of the limbs, gradually diminishing in number, but increasing in volume, and, at length, enter the lymphatic ganglions of the groin and axilla. In general, several absorbent vessels enter every conglobate gland, on the side remote from the heart, and a smaller number issue from it in the direction towards this organ.

In the trunk, also, the lymphatic vessels are distributed in two sets, one superficial, or subcutaneous; the other, situated on the internal surface of the walls of the great cavities.

In the thoracic and abdominal viscera, likewise, these vessels form two orders, an external and internal; the former, occupying the surface of these organs, the latter, apparently originating in their parenchyma.

The absorbent vessels of the small intestines, and of the mesentery, are termed *lacteals*. They originate by imperceptible orifices, at the surface of the villi of the mucous coat of the small intestines, and pass between the two laminæ of the mesentery, to a double series of small ganglions, called mesenteric glands. From these ganglions arise numerous vessels, of the same nature as the lacteals, which unite into larger trunks, and these terminate, eventually, in the thoracic duct. Some physiologists are of opinion, that the lacteals do not terminate exclusively in the thoracic duct. According to Cowper, and Tiedemann and Gmelin, there are numerous anastomoses between the chyliferous vessels and the meseraic veins. Meckel, Lobstein, and others, have observed similar communications with the vena portæ; and other physiologists have asserted their existence in various other parts. The chyliferous vessels, which issue from the mesenteric ganglions, sometimes anastomose with the radicles of the mesenteric veins. This alleged direct communication between the lacteals and the veins, has an important relation to the physiology of absorption, as will appear hereafter.

The conglobate glands, or lymphatic ganglions, are small flattened bodies, of an oval or circular shape, of different sizes, varying in diameter, from the one-twentieth of an inch to an inch. They are extremely vascular, are supplied with nervous filaments, and receive lymphatic vessels, which subdivide in their substance, forming inextricable plexuses, interwoven with innumerable blood-vessels. The lymphatics which enter them, are termed *vasa inferentia;* those which issue from them, in the direction towards the heart, are called *vasa efferentia.* If mercury be injected into the vasa inferentia, it is observed to fill a series of cells in the gland, and afterwards escapes by the

vasa efferentia. If a lymphatic gland be injected with wax, the whole substance of the gland assumes the appearance of a mass of convoluted absorbents, irregularly dilated, and which reciprocally communicate.*

The lymphatic glands are not numerous in the extremities, but are found, in abundance, in the thorax and abdomen. They generally exist in places where there is an accumulation of fat, as in the folds of the great articulations, in the anterior part of the vertebral column, and in the places where the blood-vessels penetrate the viscera. Their number is very considerable, amounting, as has been computed, to six or seven hundred; but, it appears to diminish in old age.

Two or three small absorbent glands are found at the inner ankle, four or five in the ham, and from eight to twelve in the groin. These last receive absorbents from the leg and thigh, from the pudenda, the parietes of the abdomen, the nates and the loins. Several, also, are found in the lateral parts of the cavity of the pelvis, and about the internal iliac vessels; others, on the outside of the pelvis, in the course of the glutæal and ischiatic arteries; and several minute glands are situated upon the bladder, the uterus, and the vesiculæ seminales. Numerous lymphatic glands are situated in the course of the external iliac vessels, forming a chain, which extends from the crural arch, to the inferior part of the vertebral column. Others, are found in the hollow of the sacrum, between the laminæ of the mesorectum. Large and numerous lymphatic glands occur, also, in the lumbar region, surrounding the aorta, and the inferior vena cava. They are found, also, upon the crura of the diaphragm, over the renal arteries, round the vena portæ, and along the splenic artery. The mesenteric glands, which receive the lacteals, are numerous, amounting, sometimes, to an hundred or more. They lie between the two laminæ of the

* Mayo.

mesentery, and are of considerable size. Opposite to the second lumbar vertebra, the absorbents of the mesentery, after passing through the mesenteric glands, unite into an oval sac, termed the *receptaculum chyli.* This reservoir, which receives, also, the absorbents of the lower extremities, is the commencement of the *thoracic duct*, a tortuous canal, about the size of a goose-quill, which ascends between the aorta and the right crus of the diaphragm, into the posterior cavity of the mediastinum. It then ascends behind the arch of the aorta, as high as the seventh cervical vertebra, and then arches downwards, and opens into the left subclavian vein, at the angle, where this vessel joins the internal jugular. Its embouchure is provided with a valve, derived from the internal membrane of the vein. The thoracic duct, in its course to the subclavian vein, is joined by absorbents from the viscera and the neighboring parts. It occasionally divides and unites again, particularly where it crosses from right to left, in the cavity of the thorax. The structure of this duct is similar to that of the lymphatic and chyliferous vessels; its parietes consisting of two membranes, an internal and external,—the former of which is thin and delicate, the latter is a strong, fibrous membrane, capable of opposing great resistance to a distending force.

In the thorax, lymphatic glands are found upon the diaphragm and pericardium, and around the thymus gland, and the large vessels at the base of the heart. Besides these, there are numerous glands, situated before the division of the trachea, around the bronchia, and in the interior of the lungs.

In the superior extremities, these bodies are found at the bend of the elbow joint, and clusters of them surround the axillary vessels, and their branches, and the subclavian and carotid arteries. Several small glands, also, are found behind the ear, some upon the buccinator muscle, and along the base of the jaw. None have been found within the cavity of the cranium. The absorbent vessels of the left side of the

head, and of the left upper extremity, terminate, for the most part, in the thoracic duct, but partly in the left subclavian vein itself, by two or three separate orifices. But the absorbents of the right upper extremity, open either into the right subclavian vein, or the internal jugular of the same side, and are frequently joined by the lymphatics of the right side of the head, and those from the right lung, forming a great lymphatic trunk on the right side. This, however, is very short, being seldom more than an inch in length.

The lymphatic system is a great apparatus, pervading, with few exceptions, every part of the body, and instrumental in a function indispensable to nutrition, and, consequently, to the continuance of animal life. The function of absorption is chiefly concerned in two processes, diametrically opposite to each other, but each equally indispensable to the regular repair of the organization. One of them, is the introduction of foreign substances into the circulation, to be afterwards assimilated and identified with the living organs; the other, is the decomposition of the organs, and the regular removal of their *debris*, or detached molecules, in order to make way for the deposition of the new elements of reparation. The lymphatics which originate in the mucous membranes of the alimentary canal, and the lungs, furnish the means by which the elements, necessary to the repair of the organization, are introduced; while those which spring from the parenchyma of the organs, are the instruments by which these are regularly taken to pieces, to make room for their reconstruction by the nutrient vessels. Besides these functions, subservient to nutrition, the lymphatics absorb certain parts of the secreted fluids, both of those which are deposited upon surfaces which have no external outlet, and such as are secreted upon membranes, or in sacs and canals, which are exposed to, or communicate with, the external air.

It appears, then, that the various absorptions which are regularly executed in the system, may be divided

into the five following kinds, viz. *alimentary*, *respiratory*, *interstitial*, *recrementitial*, and *excrementitial absorption*.

1. The first, or *alimentary* absorption, is executed at the inner surface of the small intestines. It is employed in the introduction of nutritious matter, obtained from the aliments and drinks, and its result is the formation of chyle.

2. The second, or *respiratory* absorption, is concerned in the introduction of an aerial principle, essential to life, into the mass of the blood. The consideration of it belongs to the history of respiration. By these two absorptions, all the materials introduced from without, for the support of life, are received into the system. These two species of absorption may be termed, collectively, *absorption of composition*.

3. *Interstitial absorption* is employed in regularly detaching from every organ a certain number of molecules, to counterbalance the action of its nutrient vessels, and thus to prevent an indefinite increase of its volume; or to preserve a proper equilibrium between composition and decomposition. It is this absorption which occasions the changes of volume in the organs, at the different periods of life; and when it predominates over nutrition, produces atrophy of particular parts of the body. It occasions the shrinking and disappearance of the thymus gland, the removal of exostoses and other tumors, and the disappearance of the red color of the bones, in animals which have been fed for a certain time with madder. It is this, also, which hollows out a canal in the callus which unites a fractured bone. This absorption varies in every organ, and is of as many kinds as there are different tissues. Interstitial absorption may also be termed *absorption of decomposition*.

4. *Recrementitial absorption*.—This takes up the fluids secreted upon surfaces which have no external outlet, which fluids would increase indefinitely, if they were not removed by absorption, as fast as they are secreted. The matters taken up by this species of absorption are very various, as the serous fluids,

the synovia of the joints, the serosity of the cellular tissue, the fat, the marrow, the coloring matter of the skin, that of the iris, and of the choroides, the humors of the eye, the lymph of Cotunnius, and the fluids exhaled into the interior of the lymphatic glands, and of the thymus and thyroid glands. The reality of this absorption cannot be denied, and is demonstrated by numerous facts. The quantity of the fat and of the marrow of the bones, varies according to the age, and state of health, and various other circumstances. Dropsies disappear by absorption. If foreign substances, solid liquid or gaseous, be placed in contact with the surfaces which secrete these recrementitious fluids, they diminish, or totally disappear, by absorption; a fact which affords a presumption, that the peculiar secretions of these surfaces must, in like manner, be subject to absorption.

5. *Excrementitial absorption.*—The excreted fluids, also, are subject to absorption, by which they are deprived of certain parts which, perhaps, may be usefully employed in the system; or by the loss of which, they are rendered more fit themselves for the uses to which they are destined in the animal economy. A great variety of fluids are subject to this species of absorption, as, for example, the fluids exhaled by the skin, and the mucous membranes, the matter secreted by the sebaceous follicles, the mucus, the cerumen of the ear, the saliva, the bile, the gastric and pancreatic fluids, the spermatic liquor, the milk and urine. Adelon remarks, that nature chooses to subject the materials of decomposition to a useful revision, before rejecting them finally from the body. By this absorption, the excreted fluids become more concentrated and stimulating; hepatic bile is converted into cystic by absorption, the urine is rendered more acrid and concentrated; and the spermatic fluid becomes more stimulating by long retention. In general, only certain principles are absorbed from the excreted fluids; but if any obstacle prevents their excretion, they are absorbed entire, and may then be sometimes detected in the blood; and, in some in-

stances, they are deposited, by a new secretion, in places remote from the organ by which they were originally secreted.

The absorptions, which have thus been described, are carried on, without intermission, in the system; and they impress certain changes upon the fluids absorbed, by which these are prepared to contribute to the formation of the common nutritive fluid, the blood; for, this fluid is the final result of the five species of absorption just enumerated. In each of these absorptions, the matter absorbed is elaborated, and changed in its properties. Thus, chyme is converted into chyle, by absorption. The oxygen absorbed in respiration, is assimilated to the blood, so that it is impossible to detect its presence in this fluid. In like manner, the molecules, detached from the tissues and organs by decomposing absorption, and the principles absorbed from the recrementitious and excrementitious fluids, do not preserve their proper characters in the lymphatics, but undergo an elaboration, by which they are converted into lymph.

But absorption sometimes occurs accidentally, or occasionally; as, for example, where certain substances, which are not of an alimentary or assimilable nature, are introduced into the system, or placed in contact with any absorbing surfaces. Substances, so circumstanced, are frequently absorbed, and they may, sometimes, be detected in the blood, in the secreted fluids, or even in the parenchyma of the organs, for, they undergo no elaboration, and their properties are unchanged by the action of the absorbents.

These accidental absorptions are of two kinds, viz. *External* and *Internal.*

The seats of the first, or of external absorption, are the two great surfaces, the skin, and the mucous membranes. Substances of various kinds, placed in contact with either of these great expansions, are subject to absorption, and may thus be introduced into the blood.

1. Solid, liquid, and gaseous substances, placed in contact with the skin, may be absorbed by this tissue,

as is demonstrated by many facts. For example, thirst may be quenched by the application of moist cloths to the skin, or by bathing. Adelon cites the case of a patient in fever, in which so much water was absorbed during the use of a foot-bath, that the level of the fluid in the vessel was sensibly lowered. It is also asserted, that the body increases in weight after using the bath, and that the urinary secretion is augmented, to carry off the water which has been absorbed. Cruikshanks witnessed the thirst quenched by bathing, and the secretion of urine, which had ceased in consequence of want of drink, restored by the bath. Falconer found that his hand, immersed to the wrist in warm water, had absorbed, in a quarter of an hour, ninety-eight grains of fluid. Hamilton observes, that the saliva has become intolerably bitter, from an absorption of sea-water. Paracelsus states, that he has supported patients by nutritive baths of milk or broth. Fontana, and others, assert, that the body absorbs moisture when exposed to a humid atmosphere. The experiments of Prof. Mussey, performed several years ago, at Philadelphia, demonstrate the absorption of the coloring matter of madder, and other substances, by the skin. Medicinal substances, applied to the skin, are frequently absorbed into the circulation, and exert their peculiar effect upon the system. A plaster of garlic, applied to the skin, has been found to impart a strong smell of garlic to the breath and the urine, which continued several hours, though the individual breathed through a tube which passed out of the apartment. In general, however, the cuticle is previously removed, or the substance is applied by friction, or *rubbed* in; otherwise, the absorption is much less considerable, for the cuticle appears to present an obstacle to the absorbing action of the skin. The cuticle, however, it should be remembered, opposes no resistance to the passage of fluids from within; and why, it may be asked, should it hinder the entrance of fluids from without. Metallic quicksilver has been found in the bones of persons who had been subjected to mercurial fric-

tions; it has been found, for example, in a carious skull, and in some other of the bones. Autenrieth and Zeller obtained quicksilver by distilling the blood of rabbits, dogs and cats, which had been rubbed with this mineral. Schubarth had a large quantity of quicksilver rubbed into a horse, from the fifth of July to the third of August, when the animal died, and, on distilling his blood, small globules of quicksilver were discovered in it.* Canter obtained, from the sediment of sixty pounds of urine, subjected to distillation, more than twenty grains of quicksilver. Quicksilver has been found, not only in the blood, and urine, but in the saliva and sweat of persons who have been severely salivated. Many animals are nourished by cutaneous absorption, and the same may be true of the fœtus, in the first periods of pregnancy, before the mouth is formed by which fluids can be received, and when the intimate connection between the fœtus and the mother, does not yet exist. Gases, also, are absorbed by the skin. Thus, the putrid miasms of a dissecting-room have been absorbed by this membrane, as has been ascertained by experiment, in which precautions were used to prevent their introduction by pulmonary absorption.

2. The mucous membranes, also, exercise an absorbing power upon various foreign substances, placed in contact with them. Alimentary substances and air, are constantly absorbed by the intestinal and the pulmonary mucous membranes. But, other principles besides chyle and oxygen, are absorbed from the aliments, and the air which we breathe; as, for example, those parts of our food and drinks which are incapable of chylification, and the vapors, or gases, with which the air we inhale, becomes accidentally impregnated. Substances not of an alimentary kind, also, introduced accidentally, or purposely, into the alimentary canal, such as medicines, coloring, odoriferous, saline, and other substances, are frequently absorbed. Chaussier

* Rudolphi.

produced asphyxia by injecting sulphuretted hydrogen gas into the intestines.

Accidental pulmonary absorption also is very active. Substances in a state of vapor, or fine dust, drawn into the lungs with the air of inspiration, are readily imbibed—such as metallic vapors, odoriferous substances, miasmatic exhalations, &c. Pulmonary absorption is, probably, one of the most frequent means, by which contagious effluvia are introduced into the system. Liquids, also, injected into the lungs, are absorbed by these organs; a fact which has been established by repeated experiments.

The mucous membrane of the urinary and genital organs, is also an absorbing surface. Fluids, injected into the bladder, are frequently absorbed; and the virus of syphilis is introduced into the system, by the same channel of the genito-urinary mucous membrane.

But, accidental absorption may take place from surfaces, or parts of the body, which have no communication with the external air. In fact, every part of the body seems to possess the power of absorbing substances, placed in contact with it, as, for example, the serous surfaces, the cellular tissue, and the parenchyma of the organs. Experiments have demonstrated, that various substances, either in a solid, liquid, or gaseous form, are subject to absorption, if placed in contact with any tissue of the body, or even buried in the very substance of the organs. Chaussier inserted a calculus in a wound, which he had made in an animal, and which afterwards healed over the foreign substance. After a time, the calculus became corroded, and finally disappeared by absorption.* Dupuytren and Magendie injected various liquid substances into the serous cavities, and cellular tissue, and found that they were absorbed. Achard, Nysten, Chaussier, and others, had observed the same fact with respect to gases, as, oxygen, carbonic acid, sulphuretted hydrogen, &c. introduced into different

* Adelon.

parts of the body. The air, which escapes into the cellular tissue, in emphysema, sometimes disappears by absorption.

The excrementitious fluids, also, when their regular excretion is prevented by any obstacle, are subject to absorption. In jaundice, the bile is absorbed into the blood, and imparts a yellow tinge to all parts of the body. In paralysis of the bladder, and in the experiment of tying the ureters in a living animal, the urine is absorbed into the blood, and impregnates all the fluids and tissues of the system. Even the contents of the large intestines, if retained a long time, are partially absorbed, and impart a feculent odor to the cutaneous exhalation. Morbid excrementitious fluids, also, as pus, if long retained, are absorbed into the blood. The blood, extravasated in the brain in apoplexy, or in any other part of the system, is sometimes absorbed. The crystaline lens is absorbed, after the operation of couching in cataract; and even the fœtus, in extra-uterine pregnancy, is sometimes removed by absorption.

According to Adelon, *accidental* absorption is distinguished from *nutritive*, by the circumstance, that, in the former, there is little or no change in the properties of the substances absorbed; whereas, in the latter, the matter absorbed is always elaborated in such a manner, that its properties are disguised, and it cannot be detected in the fluids or solids of the system. Medicinal substances, which are introduced into the system by accidental absorption from the skin or mucous membrane of the alimentary canal, retain their medicinal properties nearly, or wholly unchanged. If this were not the case, if they were assimilated by absorption to the nature of the animal fluids, it is evident, they could not exert their specific effects upon the system. So the excrementitious fluids, when accidentally absorbed, retain their properties with little alteration. When the bile is absorbed in jaundice, or the urine, in retention of this fluid, from paralysis of the bladder, or any other cause, these excretions

impregnate the animal fluids and tissues, with their own peculiar qualities.

Particular Absorptions.

It has already been observed, that there are five species of nutritive absorption, viz. *digestive* or *alimentary*, *respiratory*, *interstitial*, absorption of the *recrementitious*, and that of the *excrementitious fluids*. The second, belongs to the history of respiration, and the three last may be comprehended under a single title, viz. *internal absorption*.

1. Alimentary, or digestive absorption, is executed in the small intestines. It is exercised upon the food and drink, after these have been subjected to the action of the digestive organs. The instruments of this absorption are the lymphatics of the small intestines, or *lacteals*, as they are called. These vessels originate in the villi of the mucous coat of the intestinal canal, and, passing between the serous and muscular coats of the intestines, they proceed to the mesenteric ganglions. From these bodies there arise a second series of lacteals, fewer in number, but of a larger size, which unite together into larger trunks, and terminate, eventually, in the thoracic duct. There is a free communication between the lacteals, which enter, and those which issue from the mesenteric glands, through these bodies; for, a mercurial injection passes from one to the other without distending the glands. It is doubtful whether the lacteals open directly into the cavity of the intestines, or, whether some kind of tissue exists intermediate between their extremities, and the surface of the villi of the small intestines. However this may be, these vessels exert a peculiar vital action upon the chyme in the intestinal cavity, selecting, absorbing, and combining its nutritive principles, and converting them into a much more highly animalized fluid, termed chyle. This white, cream-like fluid, it is said, does not preëxist ready formed in

the chyme, but is the result of the action of the lacteals, upon the nutrient principles contained in it. It is affirmed, that chyle has never been discovered in the intestines, and that it is impossible to obtain it from chyme, by expression or any other means. It is formed by the elaborating action of the lacteals themselves, which, at the same moment that they absorb, impress certain vital changes upon the nutritive parts of the chyme, which hence assume the properties of chyle. In the same manner, the sap of plants does not preëxist in the soil in which they grow, but is formed by the peculiar action of the roots, which absorb the materials of it from the ground. No other substance, but chyme, which has been acted upon by the bile and pancreatic fluid, is capable of being converted into chyle; and such substances, as find their way into the small intestines, without being reduced to the state of chyme, do not contribute to the formation of chyle.

During digestion, the lacteals become filled and turgid with chyle. Various theories have been proposed to explain the mode in which this absorption is accomplished. Some physiologists have referred it to imbibition, or capillary attraction; some, to *endosmose* and *exosmose*, or the motion of heterogeneous fluids across a membranous diaphragm, separating them from each other; some, to electrical or galvanic agency; others, in fine, to a peculiar, inscrutable vital action. This last opinion, though it explains nothing, is, probably, the true one.

The action of the absorbents continues a considerable time after death, or the cessation of the circulation. After emptying some of the lacteals in an animal, soon after death, by pressing out their contents, they soon become filled again; and the experiment has been found to succeed, two hours after the extinction of life. Mascagnè observed absorption in infants to continue six hours after death, and in adults, twenty-four; and Desgenettes found it to take place sixty hours after the cessation of life, even

in very young subjects. Valentin found chyle in the lacteals, as late as three days after death.*

The quantity of chyle which is formed in a given time, is uncertain. Magendie found that, in a dog of a common size, which had eaten heartily of animal food, more than half an ounce of chyle issued from an opening in the thoracic duct in five minutes, and it continued to flow out for several hours. This would imply a pretty rapid formation and motion of the chyle; for, at this rate, six ounces must have entered the circulation in an hour. Emmert estimated the quantity which flowed from the thoracic duct of a horse, at a pound in half an hour. In man, the quantity formed must be proportionally large, but it is evidently impracticable to arrive at any precision in estimating it.

The chyle appears to be constantly undergoing changes in its properties, in its passage through the absorbent system. Its albuminous qualities seem to diminish, while the proportion of its fatty matter, and of its fibrin and cruor, appears to increase. Its tendency to coagulate, also, increases as it approaches the venous system, and becomes very considerable in the thoracic duct. In the large lymphatic trunks, or those between the mesenteric glands and the thoracic duct, the chyle gradually loses its opaque, and milky or cream-like appearance, and becomes clearer and more transparent. It is also remarked by Emmert, that, in the smaller lacteals, near the origins of these vessels, the chyle is more homogeneous in its appearance and properties; but, in the larger trunks, it gradually becomes more heterogeneous. In the thoracic duct, it has sometimes been observed of a reddish color. Chyle, obtained from the smaller lacteals of a horse, was found to be milk-white; while that from the larger trunks, and the receptaculum chyli, was yellowish; and the chyle of the thoracic duct still more so. Exposed to the air, it assumed a pink or peach-blossom color. These changes are probably produced, partly

* Le Pelletier.

by the vital influence of the lacteals themselves, exerted upon the chyle, and partly, by the action of the mesenteric glands. It is, however, impossible to determine, what are the functions of these bodies. It is conjectured, by some physiologists, that the chyle undergoes some peculiar modification in traversing these glands. Some are of opinion, that they produce a more intimate combination of the elements of the chyle; others, that they secrete a peculiar fluid, which is destined to dilute it; while some suppose, that their office is to purify this fluid, by separating from it certain heterogeneous principles.

Absorption takes place throughout the whole alimentary canal. Even in the mouth the absorbents imbibe some part of the food, as is evident from the effects of wine or spirits, held in the mouth. It is probable, also, that the absorbents of the œsophagus imbibe something from the aliment during its passage through this tube. The lymphatics of the stomach are found to be turgid during digestion. But, the chyliferous absorbents of the small intestines are particularly active during digestion, in imbibing the nutritious chyle. These vessels diminish in number, in the inferior portion of the small intestines. But some are found in the large intestines, and their effects are evident in the increasing density and consistency of the contents of the lower part of the alimentary canal. In horses and some other animals, the absorbents of the large intestines are observed to be filled with a chyle-like fluid.

As chyle is found only in the lacteals, and yet, as just observed, absorption of nutritious substances takes place from the whole surface of the alimentary canal, it appears, that alimentary matter may be imbibed from the intestines, without having undergone the preparatory process of gastric digestion. Persons have been nourished for many days, and even weeks, by injections of milk, broth, and other nutritive fluids, thrown up the rectum. The author had a patient who was supported four weeks, *almost* exclusively, upon injections of animal decoctions and wine. No

food whatever could be taken the greater part of this time. A few drops of sage tea, or even pure water, would occasion the most dreadful anguish; and it is a question with the author, whether food enough was swallowed, during this whole period, to form one gill of chyle. This patient completely recovered, and is now in the enjoyment of good health. Now, it is evident that alimentary substances, directly absorbed from the intestines, can undergo no assimilation previous to their reception into the circulation, except that, which they receive in their passage through the absorbent system; a consideration which appears to establish the conclusion, that the absorbents exert an elaborating influence upon the substances absorbed, which, under some circumstances, may serve as a substitute for digestion in the stomach and small intestines; and it affords some corroboration of the principle, that every living animal substance, solid as well as fluid, possesses a power of assimilation, by virtue of which, it constantly tends to subdue to its own nature substances applied to, or mixed with it, and to communicate to them its own properties. In cases of extreme irritation, it should seem that alimentary matter is sometimes absorbed so greedily as not to allow time, either for chylification or any other considerable change to be effected. We are told of a young man, almost dead of hemorrhage, supported by broth, in whom the last discharge of blood had the smell, taste, and even color of this substance. He eventually recovered, and grew fat. Le Pelletier expresses the opinion that, hematosis, or the formation of blood out of the aliments, commences at the origin of the absorbents, that it is continued by the action of these vessels, by that of the mesenteric ganglions, and by the veins, and that it is finally consummated in the capillaries of the lungs, by the influence of respiration.

It has already been observed, that, after long fasting, the lacteals, instead of containing chyle, are filled with real lymph. But, according to Magendie, after twelve, twenty-four, or even thirty-six hours of total

abstinence, the lacteals of a dog contain a small quantity of a semi-transparent fluid, of a slightly milky appearance, which he supposes to be chyle, formed by the digestion of the saliva and the mucus of the stomach. But, if the fasting be prolonged beyond three or four days, the lacteals are found sometimes filled with lymph, and sometimes entirely empty.

Venous absorption.—Many physiologists of the present day, have adopted the opinion, founded on various facts and considerations, that the absorption of the chyle, and of other substances from the alimentary canal, is not effected, exclusively, by the lacteals. Some of the experiments and facts, on which this opinion is founded, will be noticed.

Magendie gave a dog four ounces of an infusion of rhubarb, and half an hour afterwards, not a trace of it could be discovered in the thoracic duct, though the urine of the animal indicated its presence, and half of it had disappeared from the alimentary canal. Segalas injected an infusion of nux vomica into a part of the intestines, isolated by two ligatures, having tied the blood-vessels of the part, but left the lacteals untouched. In one hour no appearance of poisoning had taken place; but, in six minutes after removing the ligatures from the blood-vessels, symptoms of poisoning appeared. Berthold injected water, colored with ink, into a piece of intestine of a puppy, isolated in like manner, by two ligatures, and, in ten minutes the fluid had partly disappeared from the intestine, and the veins of the part were filled with it, but the lacteals were entirely empty. According to Boerhaave, the blood of the mesenteric veins, becomes more fluid during the digestion of fluids; and Flandrin thought, that he perceived an herbaceous smell in the blood of these vessels, in a horse, which had been eating food of this kind. Kaaw Boerhaave injected warm water into the stomach and intestines of a dog, just killed, and, by a little pressure, this water passed into the meseraic veins, so that these vessels became pale, and, at last, clear water flowed out of the vena cava inferior. The result was similar

with calomel water. Lieberkuhn pushed an injection into the vena portæ, and saw the matter of it ooze out of the villi of the intestines. Ribes obtained the same result with essence of turpentine, colored black, and with mercury—facts from which it appears, that the meseraic veins have open orifices in the cavity of the intestines. Flandrin gave a horse a mixture of honey and asafetida, and the venous blood of the stomach and intestines exhaled the peculiar odor of the asafetida, while the chyle and the arterial blood were wholly free from it. Magendie caused a dog to take diluted alcohol, a solution of camphor, and other odorous substances, and, on examining the chyle, half an hour afterwards, no trace of these substances could be detected in it; while the blood exhaled the odor of alcohol, camphor, &c. and these substances could be even obtained from the portal blood by distillation. The same physiologist gave a dog two ounces of a decoction of nux vomica, after tying the thoracic duct, and death took place as speedily as in another, who had swallowed the same poison without having had the duct obstructed by a ligature. In another dog, he isolated a piece of intestine by two ligatures, and divided, with the utmost care, all the vessels of the part, arterial, venous, lymphatic, and chyliferous, with the exception of a single artery and vein, which were left undivided. He then separated the piece of intestine from the rest of the canal, so that it was connected with it only by a single artery and vein, and injected into it a decoction of nux vomica, and, in six minutes, the effects of the poison manifested themselves. Flandrin sometimes found the substances injected, in the veins only; sometimes, in the lacteals only, and sometimes in neither, but only in the urine. Haller found that the blue juice of the heliotrope, which he had injected into the stomach, was present in the chyle, but not the red coloring matter of madder, nor the yellow of saffron. Emmert showed that madder curcuma, prussiate of potash, nitrate of silver, &c. are received into the chyle.

The researches of Tiedemann and Gmelin, of

Germany, and of Lawrance and Coates, of our own country, corroborate the conclusion, that absorption from the alimentary canal, is not exclusively the function of the lymphatics, but is shared with them by the mesenteric veins. In the experiments of Tiedemann and Gmelin, various coloring, odorous, and saline substances, were introduced into the stomach, and the urine, the portal blood, and the chyle of the thoracic duct, were afterwards submitted to the proper tests, or the presence or absence of the substances absorbed, was ascertained by their color or smell.

It appeared from these experiments, that coloring substances were not absorbed by the lymphatics or lacteals, as they could, in no instance, be detected in the chyle of the lacteals, or that of the thoracic duct, either by their smell, or by the aid of chemical tests, though they were detected in the urine, and in the serum of the blood of the *vena portæ;* facts which demonstrated, that they entered the circulation by venous absorption. The same results were obtained with odorous substances. They were detected in the urine, and in the portal blood; but in no instance were they discovered in the chyle of the lacteals or thoracic duct.

Saline substances, of which several were employed, as the prussiate of potash, the muriate of barytes, the muriate and sulphate of iron, and the acetate of lead, were discovered in the urine, and several of them in the blood of the mesenteric veins; a *very* few of them, also, were detected in the chyle of the thoracic duct.

On the whole, they inferred from these experiments, that the office of the lacteals is, to absorb the nutritious matter formed by digestion, and to convey it to the thoracic duct; while the roots of the mesenteric veins absorb substances which are not of an alimentary nature, as saline, coloring, odorous, and metallic, and, probably, medicinal and poisonous substances. Rudolphi, however, remarks, in answer to these conclusions of Tiedemann and Gmelin, that nothing ex-

ists in the urine, which did not previously exist in the blood. Now, it is certain, that many substances can be detected in the urine, which cannot be discovered in the blood. So, in the chyle, many principles may be present, but not sufficiently concentrated to be detected by chemical or other tests. Roose proved, that the serum of the blood, as well as a filtered solution of the white of eggs, might contain a considerable quantity of oxyd of iron in solution, without the possibility of detecting it, by the usual agents; and he established the following principles, viz. that all organic substances, soluble in water, which are decomposed by exposure to a high temperature, possess the property of preventing the precipitation of the oxyd of iron, and of other oxyds, by alkalies; and, on the contrary, all organic substances, soluble in water, which are completely or partially volatilized, *without decomposition*, by a high temperature, do not possess this power.*

The experiments of Lawrance and Coates, led to results similar, in the main, to those of Tiedemann and Gmelin. The prussiate of potash was introduced into the stomach, and the blood of the *vena portæ* afterwards examined. On the addition of a salt of iron, the portal blood assumed a blue color, more or less intense, indicating the formation of the Prussian blue. The chyle of the thoracic duct was also found to contain the prussiate of potash, evincing that the absorption of the salt had been effected, partly by the lymphatics. In some of the experiments, the portal blood was found exclusively to contain the salt, the chyle of the thoracic duct presenting no trace of it; in some others, precisely the reverse of this occurred. But the authors remark, that the general weight of evidence was strongly in favor of the principal absorption having taken place through the *vena portæ*. The fact was more conclusively established by tying the thoracic duct, and thus intercepting the communication between the lymphatics and the circulation.

* Rudolphi.

In one experiment, in order to stop every known communication between the absorbent system and the circulation, the thoracic duct, and the trunk of the lymphatics, on the right side of the neck, were both secured by ligature. Yet, the blue color was produced in the serum of the blood, taken from the right side of the heart, in twenty minutes.

On the whole, it appears that, the lacteals absorb chyle much more readily than other substances. Coloring, odorous, and mineral substances, perhaps poisons, and, in general, matters not of an assimilable nature, are absorbed with difficulty by the lacteals, and much more easily by the veins. Some unchymified substances, of an alimentary nature, as milk, are absorbed by these vessels. Rudolphi says, that he has seen a whitish blood flow from the vessels of the head, in sucking puppies, on cutting into the diploe, from which blood, a large quantity of bluish white fluid, perfectly like milk, soon separated itself. Lown, also, found milk in the blood, drawn from a vein, soon after food had been taken; and Viridet mentions a case, in which a person, in an attack of fever, drank a quart of milk; and, on bleeding him, soon after, a stratum of milk formed on the blood. In cases of long fasting, the lacteals absorb the animal juices, and become filled with intestinal fluid, bile, &c. and frequently with true lymph.

Several distinguished physiologists assert a direct communication between the absorbent vessels and the veins. Blizard and Meckel observed lymphatics terminate directly in veins. Ribes, in injecting the supra-hepatic veins, saw the matter pass into the superficial lymphatics of the liver. According to Mertins, a considerable part of the chyle is carried directly into the *vena azygos*, and the lumbar veins, and others, by the lacteals. Meckel, Lobstein, and others, have observed similar communications with the vena portæ; and other physiologists have asserted their existence in various other parts. Lizars remarks, that some of the lymphatics, almost as soon as they originate, join the veins in the capillary tissue;

others anastomose with the veins in the lymphatic glands, while a third class concentrate to form the thoracic duct. Aselli, the original discoverer of the absorbent system, was persuaded, that the lacteals terminated in the vena portæ; an opinion which, according to Mayo, the observations of Fohman have proved to be partially true, showing that many of the lacteals open into the branches of the visceral veins. But, an Italian anatomist, Lippi, has carried this opinion to a much greater extent. He has endeavored to prove, that the absorbent vessels of the abdomen open freely into the iliac, the spermatic, the emulgent, and lumbar veins, and the vena cava, as well as into the branches of the portal system; and, that they communicate with the venous system, not only by opening into the great venous trunks, but by anastomosing with the small veins, which issue from the conglobate glands, and by direct continuity with the capillary veins. He also affirms, that several absorbent trunks, in the abdomen, terminate directly in the pelvis of the kidneys. He does not think that any communication exists between the absorbents and veins in the limbs. This alleged communication between the absorbents and the veins, is regarded, by many physiologists, as imaginary. Rudolphi treats the opinion with contempt, but Mayo observes, that he thinks it not unlikely, that such communications do exist, even in the limbs; for, he has sometimes seen mercury, thrown into the absorbents of the limbs, unaccountably make its way into the veins. He also states, that, on injecting the arteries of the mesentery of a dog, with ink, he observed the veins next, to become filled with a black fluid, and then the lacteals; and he further says, that he has certainly seen, in one instance, the absorbents of the liver filled with colored injection from the hepatic artery. Adelon doubts the reality of this communication, and regards it as a cadaveric phenomenon. According to Camper, and Tiedemann and Gmelin, there are numerous anastomoses between the chyliferous vessels and the meseraic veins. In experiments, performed by these two

last named physiologists, on two dogs, a horse, a cow, and three human bodies, the lacteals were injected with quicksilver; and in all of them, the metal reached the branches of the mesenteric veins, and the vena portæ, without the application of any external force. On close examination, it was discovered, that the communication of the lacteals with the veins of the intestines, took place in the mesenteric glands, and that all the veins, proceeding from a gland filled with quicksilver, also became filled with the metal; a fact which proved, that it passed from the lacteals, through the gland, directly into the veins proceeding from it. In several of their experiments, these physiologists observed, in the portal blood, white streaks, resembling chyle, and which they supposed to be really such; an appearance, which was readily explained by their discovery of a communication, between the lacteals and the meseraic veins, in the glands of the mesentery. The chyle, thus entering the portal circulation, and conveyed with it to the liver, they supposed to be elaborated in this gland, by the separation of its heterogeneous principles in the secretion of bile.

Rudolphi, however, gives no weight to the experiments, in which quicksilver has been observed to pass out of a gland into a vein. He supposes, in these cases, that this ponderous metal forced for itself new passages. He admits that quicksilver, injected into an absorbent, frequently passes into a vein; but he explains the fact, by asserting that, either the vein lying under or near the absorbent, has been wounded by the injecting tube, or, what he says is most frequently the case, that the quicksilver has passed from the absorbent vessel into the thoracic duct, left subclavian vein, through the superior vena cava into the inferior, and thence to the place where the injection was made. This passage of the injected quicksilver through the thoracic duct, superior and inferior cava, &c. takes place, he asserts, in a moment. Rudolphi further objects, that if such communication really existed between the veins and lymphatics, it would

be impossible to inject the latter with quicksilver, for, all the metal would pass into the veins. He admits that, in birds, anatomists, at present, regard the immediate communication of the absorbents with the veins, as fully established. When the lymphatics in a duck's foot are injected with quicksilver, the metal is *always* soon found in the lumbar veins. But, he says, that it is impossible to discover the communication. On opening the vein, no orifice of a lymphatic can be detected in it; but the lymphatic may be traced to the kidney; and here, he thinks, the connection exists by which the quicksilver gets into the veins. He supposes that, in the kidneys of birds, which are very large, a particular connection may exist between these two orders of vessels. This important question cannot yet be considered as settled; though, to the author, the arguments in favor of the communication of the absorbents and the veins, appear to preponderate.

It appears, that the thoracic duct may be obstructed, and yet chyle find its way into the circulation. In two instances, Sir A. Cooper found this canal obstructed in human subjects; but, in both, collateral vessels ascended from below the obstruction, and opened into the duct above it. Dupuytren tied the thoracic duct in horses, some of which died, while others survived the operation. In one, which was opened six weeks after the operation, the canal was found perfectly closed at the place where the ligature was applied; but there were found connecting vessels, which passed from the part of the duct below the ligature, to the subclavian vein. But, in an experiment, performed by Leuret and Laissaigne, the thoracic duct of a dog was tied, and the animal lived, and even thrived, fifty-eight days, at the end of which time he was killed; and, upon opening him, the thoracic duct, which was single, was found perfectly closed. The accuracy of this statement seems to be doubted by Rudolphi, and very naturally, as, if admitted, it appears decisive of the question of the passage of chyle into the circulation, by other channels

than the thoracic duct. Flandrin repeated the experiment of tying the thoracic duct on twelve horses, which lived and retained their flesh and appetite. On killing and opening them, a fortnight afterwards, he found that the thoracic duct was not double.

The passage of the chyle into the left subclavian vein, it is said, takes place only by drops; and the conversion of chyle into blood is effected, not at once, but by degrees, and after many revolutions of the blood through the circulating system. Haller thought that eighty thousand revolutions of the blood were necessary, to complete the conversion of chyle into this fluid. Ploucquet says, that chyle requires ten or twelve hours in order to be converted into red blood; and Autenrieth adds, that, in blood drawn from man, or other animals, within this time, the serum is sometimes found milk-white. In this view, it is apparent, that the secretions and excretions, particularly the urine, by removing the unassimilable principles from the imperfect blood, may contribute essentially during its circulation through the body, to its complete sanguification. The opinion, that the chyle is not immediately converted into blood, is founded, partly on the appearance of white streaks and flakes, which have sometimes been observed in the blood, a few hours after digestion. These streaks Haller took to be chyle. He had even seen, in living animals, white chyle, floating in the blood, issue from a wound or enter the heart. This white appearance, however, disappeared some hours after eating, and the whole mass of the blood resumed its usual red color.

In some instances, instead of the blood presenting the appearance of white streaks or flakes, the whole mass of it has been observed to be colored white, presenting the appearance of milk or cream, for a longer or shorter time. This appearance of the blood has been observed in individuals of scorbutic or cachectic habits, or, of corpulent persons.

These appearances of the blood probably depend on different causes. When occurring a few hours after eating, the white streaks are, perhaps, owing

to unassimilated chyle, especially when fat, oily, or milky food has been eaten, and the powers of digestion and hematosis are enfeebled. In other cases, they may be owing to pathological states of the blood, as in scurvy, chlorosis; or, as Hewson supposed, to the absorption of fat, milk, pus, or other substances. Emmert regards this appearance, not as chyle, but as a sign of an inflammatory condition of the blood, and analogous to the pleuritic crust.

Internal absorption.—From the analogy, in structure, of the lymphatics with the lacteals, which, unquestionably, absorb a nutritive matter from the intestines, from the lymphatics, constituting a part of the same system of vessels, and from the universality of their distribution, it has been inferred, that their office is to absorb, and to convey to the circulation, the elements detached from the organs, and certain principles separated from the secreted and excreted fluids. The direct proofs of this function of the lymphatics, however, are not perfectly conclusive; and one of the most eminent physiologists of the age, considers the general doctrine as resting on insufficient grounds. Some of the most important facts in favor of lymphatic absorption, are the following:—

Whenever acrid or poisonous substances, as, for example, the venereal virus, are imbibed into the system, or when a person, in dissecting a dead body, is accidentally inoculated with the septic poison, with which corpses are sometimes tainted, it is generally the lymphatic system, which first discovers marks of irritation. The lymphatic vessels, originating near the part to which the poison is applied, frequently become inflamed, presenting the appearance of red lines, and the lymphatic glands, to which they lead, sometimes become enlarged and tender.

Mascagni found in animals, which had died of pulmonary or abdominal hemorrhage, the lymphatics of the lungs and peritoneum full of blood. He also observed, in one instance, all the lymphatic vessels filled with the fluid of a dropsy. Desgenettes observed the lymphatics of the liver to contain a bitter lymph, and

those of the kidneys, lymph impregnated with urine. Sœmmering saw the lymphatics of the liver, filled with bile, and those of the axilla, with milk. And Dupuytren observed the lymphatics and the lymphatic glands, in the neighborhood of a large suppurating tumor, situated at the internal part of the thigh, filled with a fluid, which had the characters of pus.* In caries of the bones, according to Sœmmering, the lymphatics, in that vicinity, have been seen filled with calcareous earth. Hunter injected water, colored with indigo, into the peritoneum; and saw the lymphatics of the abdomen assume a blue color. The extirpation of the lymphatic ganglions, if practised immediately after the insertion of certain poisons, or infectious matters, prevents the absorption of the latter, in the corresponding points. So, in cases of extravasation, the lymphatic vessels, which originate in the seats of the extravasated fluid, become engorged with it. In the experiments of Lawrance and Coates, which consisted in injecting certain substances, as the prussiate of potash, into the cavity of the abdomen, the chyle of the thoracic duct was found to contain this salt. When it was injected into the trachea of a living animal, its presence was detected in one case, in the thoracic duct; and, in two or three instances, indications of its presence were detected in the right side of the heart. In another curious experiment, a saturated solution of prussiate of potash was injected into the cellular tissue, over one side of the abdomen, and the same quantity of a strong solution of sulphate of iron was thrown into the cavity of the abdomen, on the opposite side. In thirty-five minutes, the animal was bled to death; and, on examination, the lungs were found to be of a deep blue color, throughout their whole texture. The *thoracic duct*, in its course in the thorax, was of a deep blue; the *chyle* contained in it, the urine, and the coagulable lymph of the blood, were all blue. The day after, the chyle had thrown down a blue deposit. Mascagni mentions an experi-

* Adelon.

ment, which he made upon himself, and which appears decisive of the question of lymphatic absorption. Having immersed his feet several hours in water, he observed a slightly painful tumefaction of the inguinal glands, and a transudation of the fluid through the gland.

From these and other similar facts, the absorbing function of the lymphatics is almost universally admitted; but several distinguished physiologists have revived the ancient doctrine of venous absorption, contending that the veins share this function with the lymphatics; and one eminent experimentalist has attempted to prove, that absorption is the *exclusive* prerogative of the veins. The subject of absorption, in relation to the mesenteric veins, has already been considered. If it be true, that these veins partake, with the lacteals, in the office of absorbing substances from the alimentary canal, analogy would justify us in concluding, that the veins, in other parts of the system, must participate, with the lymphatics, in the same function. A well-known experiment of Magendie, has been considered as placing the doctrine of venous absorption beyond controversy. He separated the thigh of a dog from the body, dividing all the parts except the femoral artery and vein. Into each of these vessels, he introduced the barrel of a small quill, upon which each of the vessels were secured by two ligatures, and then divided, in a circular direction, between the ligatures; so that the two columns of blood, flowing in opposite directions in the femoral artery and vein, constituted the only vital connection between the limb and body of the animal. Two grains of a very subtle poison were then forced into the cellular substance of the foot, and, in about four minutes, the poison manifested its peculiar effects upon the animal. This experiment, however, does not appear absolutely decisive of the question, because, in forcing the poison, by a blunt instrument, into the cellular substance of the foot, some of the small veins must, unavoidably, have been lacerated; and, in this way, a portion of the poison directly

introduced into the returning blood. Or, the poison might have been imbibed by the coats of the veins. The experiments of Lawrance and Coates demonstrate the absorption of the prussiate of potash from the lungs, by the pulmonary veins, the salt being detected in the left side of the heart, in a few minutes after being injected into the trachea. According to Mayer, also the prussiate of potash injected into the lungs, is found in the blood sooner than in the chyle, and sooner in the left than in the right side of the heart. Yet when large quantities were injected, it was found largely in the venous blood of the right side of the heart, and in the inferior vena cava.*

Absorption from the cellular tissue by veins, was also demonstrated by Lawrance and Coates, by repeating the experiment of Magendie, with the variation of substituting the prussiate of potash for a powerful poison. The result was equally striking, but like the other, perhaps, not wholly free from fallacy.

In their experiment upon the prussiate of potash, injected into serous cavities, they found that absorption was accomplished principally, if not exclusively, by the lymphatics.

Magendie states that himself and Dupuytren had made more than one hundred and fifty experiments, in which they had exposed a great number of different fluids to absorption, by the serous membranes, and that they had never seen them find their way into the lymphatics. The substances thus introduced into the serous cavities, produced their peculiar effects upon the system, with the same promptitude where the thoracic duct was tied, as when this canal was left unobstructed. Opium stupified; wine intoxicated; &c.

Adelon is of opinion, that both veins and lymphatics are concerned in internal absorption, interstitial, recrementitious, and excrementitious. These two orders of vessels, he observes, are equally extended from the parts where absorption takes place, to the

* Rudolphi.

centre of the circulation. They are both *returning* systems of vessels, and have their origins at the external and internal surfaces, where absorption occurs. An injection thrown into a vein or lymphatic, equally penetrates into the parenchyma of the organs, and oozes out at the surfaces, which are the seats of the recrementitious function. The lymph and the venous blood, which circulate in these two orders of vessels, have the same distinction, viz.—after being blended with the chyle, which is another product of absorption, to be converted in the lungs into arterial blood. The lymphatics and the veins have equally a capacity superior to that of the arteries; and hence there are the same reasons to believe that both of these orders of vessels return to the centre of the circulation *something more* than the residue of the arterial blood. Adelon is of opinion that the materials of internal absorption are not merely imbibed, but are changed into lymph and venous blood at the moment of their absorption. Venous blood, he says, is as much formed by venous absorption, out of the materials absorbed by the veins, as chyle is by the lacteals out of chyme. Neither lymph nor venous blood exists before the action of absorption.

Several distinguished physiologists, however, are of opinion, that substances which find an entrance into the veins, are not absorbed by the mouths of these vessels, but penetrate through thin coats by *imbibition*. Mayo mentions the following facts, most of them taken from Magendie, in favor of this opinion. A piece of fresh meat put in common salt, in a few days becomes penetrated throughout its whole mass with salt. In an animal opened some time after death, the parts in the vicinity of the gall-bladder are found deeply tinged with bile. If the theca vertebralis be opened in a living animal, or soon after death, it is found to contain a certain quantity of fluid; but a like quantity of fluid is not found in it if the examination be delayed till some time after death. If half an ounce of acidulated water be thrown into the pericardium of a dog killed twelve hours before, and a con-

tinual stream of warm water be injected into the coronary arteries, so as to flow into the right auricle, in four or five minutes it gives unequivocal evidence of containing an acid. In an animal killed by a poisoned arrow, the parts near the wound become impregnated to the depth of several lines, with a brownish yellow color, with the bitter taste belonging to the poison.

That imbibition takes place in living animal matter, also, is established by many facts. If a drop of ink be put on the peritoneum of a living animal, it soaks into it, and forms a large circular stain, which penetrates through the membrane, and, after a considerable time, to the subjacent tissues. If a small quantity of ink be introduced into the pleura of a puppy, in the course of an hour, the pleura, the pericardium, the intercostal muscles, and the surface of the heart itself, assume a blackish tinge. If the jugular vein of a living puppy be raised from its place, and separated from the neighboring parts by a piece of card, and the vessel be carefully denuded of the surrounding cellular textures, and a strong aqueous solution of the alcoholic extract of nux vomica be placed upon the middle of the card, so as to surround and bathe the vein, the usual effects of the poison manifest themselves in less than four minutes. Magendie found the same results to follow when the experiment was made on a large arterial trunk; only they were much less prompt, owing to the greater thickness of the arterial coats, and the superior compactness of their texture. More than a quarter of an hour was necessary, for the passage of the nux vomica through the coats of the artery. Emmert saw all the symptoms of poisoning with prussic acid, produced in a couple of rabbits, by applying the oil of bitter almonds to the sound skin of the back. The muscles under the skin, even as deep as the bones, had the smell of the prussic acid.

The effect of suction, of ligatures, and of the application of cupping glasses in preventing the absorption

of poison, are all favorable to the idea, that it finds a passage into the system by imbibition.

Magendie ascertained the fact, that a state of distension of the vessels is unfavorable to imbibition. He injected a large quantity of water into the veins of a dog, and having introduced a poison into the cavity of the pleura, he waited nearly half an hour to witness its effects, which in other cases required only about two minutes to manifest themselves. He then bled the animal largely in the jugular vein, and as the blood flowed, the poison began to manifest its effects. Hence he concluded that absorption is inversely as the distension of the vessels. On the same principle, perhaps, absorption is promoted by inanition, exhausting discharges, and all causes which diminish the mass of the fluids, or retard the motion of the blood. Hence medicines act with most power if given in the morning on an empty stomach. Exposure to contagion is said to be most dangerous under the same circumstances. Absorption is very active after long sickness, after the operation of purgations, after blood-letting, and long fasting. Intoxication is most apt to occur *cet. par.* in hungry, feeble, and exhausted persons. On this principle, probably, depends the quicker appearance of extravasated blood, dropsical effusion, &c. under a scanty diet.

Magendie conjectures that the cause of imbibition is the affinity of the coats of the vessels for the substances absorbed. The serous membranes, and the cellular tissue, according to the same physiologist, are particularly during life, the best agents of imbibition.

Fodéra ascertained that imbibition is very much accelerated by galvanism. A solution of prussiate of potash, was injected into the pleura, and a solution of sulphate of iron, into the abdomen of a living animal. Under ordinary circumstances, five or six minutes are required for the two substances to come into contact, by imbibition through the diaphragm. But if a light galvanic current were transmitted through

the diaphragm, the passage took place instantaneously. The same result was obtained, when one of the solutions was placed in the urinous bladder, and the other in the abdomen; or one in the lungs, and the other in the cavity of the pleura.

It appears, on the whole, that the subject of venous absorption, is involved in no little obscurity, though the facts and considerations in favor of this alleged function of the veins, appear to preponderate over those of a contrary tendency. Whether, however, subtances, which obtain an entrance into these vessels, are absorbed by open orifices, or are imbibed by their coats; or, whether they find their way thither by both these avenues, is a question of secondary importance. The great fact seems to be fully established, that many foreign substances find their way into the system, principally, if not exclusively by this channel, and, whether they owe this prerogative to a vital or a physical cause, is evidently of no consequence; since, in either case, the result, as far as we know, is the same, and the means of effecting it were undoubtedly not a matter of accident, but of choice.

Lymph is obtained with difficulty from the lymphatic vessels, on account of the tenuity and transparency of these vessels, and the circumstance that they are not always filled with this fluid. It may, however, be obtained from the thoracic duct of an animal which has been kept from food for three or four days. It then presents the following characters. It is a nearly transparent colorless fluid, or, according to some physiologists, of a slightly opaline color, tinged with red. Its rose color is said to be deeper, the longer the animal, from which it is taken, has fasted. It has a strong spermatic odor, and a saline taste.

The motion of the lymph is slow. When one of these vessels is punctured, the lymph is said to issue out very slowly. The lymphatics possess a contractile power, and frequently, empty themselves as soon as they are exposed to the air. Hence they are almost always found empty in an animal recently

dead. Their contractile power may probably be assisted by the mechanical compression, which they undergo from the contraction of the neighboring muscles; from the pulsation of the arteries, with which they are in contact; from the pressure of the distended hollow organs, and other causes; and the motions there impressed upon them, and communicated to their contents, are determined by the disposition of their valves in the direction of the thoracic duct, when it mingles with the chyle.

The conglobate gland have been supposed to perform the office of more completely assimilating the heterogenous principles, which enter into the composition of the lymph, and perhaps of arresting and separating any noxious ingredient, so as to prevent its passage into the blood-vessels. In favor of this last conjecture, may be mentioned the swelling of the conglobate glands, which lie in the course of branches of the lymphatics, by which poisonous or noxious substances have been absorbed. In these cases, which are of common occurrence, the poisonous substance appears to be arrested in its course to the circulation, by the lymphatic gland, which it irritates and inflames, and which sometimes suppurate, a process, by which the poison may be destroyed or evacuated. Or, if suppuration should not take place, the noxious principle may be neutralized or assimilated, by the peculiar action of the gland, and thus disarmed of its power of doing mischief.

In certain situations, or, under particular circumstances, the lymphatic glands become colored. Thus the glands, which receive the lymphatics of the liver, are of a yellowish color, derived probably from the coloring matter of the bile. The bronchial glands are black; the mesenteric glands of animals fed with madder, become red; facts, which render it probable that the coloring matter is arrested in its course to the circulation, and perhaps, after a time, assimilated or destroyed by the peculiar action of the gland.

CHAPTER XVIII.

Secretion.

In speaking of the fluids of the system, it was observed, that they might be divided into three classes, viz: 1. those which serve for the preparation of the blood; 2. those which are formed out of the blood; and 3. the blood itself. The first and the last of these, viz. the chyle, lymph, and the blood, have already been described. It remains in this place to consider the second class, viz. those formed out of the blood, or the *secreted* fluids, and the process by which they are prepared, or, the FUNCTION OF SECRETION.

Secretion may be defined *the vital action of the secretory organs upon the blood, by which they extract from it, and combine together the elements of a fluid, which had no existence in the blood, previous to this elaboration.* This function is one of the most obscure and mysterious, in the animal economy. The vessels subservient to it, Mr. Hunter used to call the architects and chemists of the system, expressing by these terms the plastic powers of these agents, which, out of the same homogeneous fluid, the blood, could construct such a variety of wonderful fabrics, and compound such a diversity of chemical products.

The vital nature of the function of secretion, is evident from many facts and considerations. The division or compression of the nerves, distributed to a secretory organ, is said to suspend this function, and the peculiar fluid prepared by the organ, we are told, is no longer secreted. The secretions are also liable to great variations in their degrees of activity, and in their results, from the peculiar condition of the vital powers of the secretory organs. Hence the secreted fluids are constantly changing, not only in quantity, but in their qualities, in consequence of the fluctua-

tions, occurring in the state of the vital powers of the glands, which prepare them. Moral causes, as is well known, have a powerful influence upon the secretions. Sorrow and profound grief pervert the qualities of the bile. A fit of anger sometimes causes an increased secretion of this fluid. The same passion has also been known to produce such a change in the qualities of the milk, in a nurse, that the child which she suckled, was frequently seized with vomiting and convulsions; a fact, which, Le Pelletier says he had often witnessed.

Morbid states of the secretory organs, materially affect the qualities of the fluids prepared by them. Thus the cellular membrane, and several of the other surfaces, when inflamed, secrete pus; the pleura and peritoneum, when in the same morbid state, secrete fibrin and sometimes pus. The bile in a diseased state of the liver, differs materially from the healthy fluid; and the secretion of the kidneys becomes exceedingly depraved in certain diseases of these organs.

In its simplest form, secretion seems to be merely a separation of some element or principle already existing in the blood. In this manner a serous fluid is separated from the blood, and deposited upon certain surfaces by a kind of arterial exhalation. This kind of secretion may be illustrated by a fact, which is observed, when the body is injected with size and vermillion, thrown into the aorta; for then, there is found in the serous cavities, a quantity of colorless size, which must have been strained through very minute orifices.* That this is not a mere mechanical filtration, however, is evident from the fact, that, when membranes, which, in their healthy state, are lubricated by a serous exudation, become diseased, the fluid, exhaled by them, differs materially in its properties from the healthy secretion. Warm water injected into the veins, also, filters through serous surfaces.

* Mayo.

It has been ascertained by experiment, that the blood contains, ready formed, some of the principles which exist in certain of the secretions, as well as some of the peculiar kinds of animal matter, of which the organs are composed. Thus fibrin, or the basis of muscular flesh, is one of the elements of the blood. A peculiar substance, ascertained to be the basis of nervous matter, has also been detected in the blood. Some of the elements of the bile, also, have been discovered in the serum of the blood. Another curious fact discovered by Prevost and Dumas, is that, after the extirpation of the kidneys, a sensible quantity of *urea* may be found in the blood; from which it has been inferred, that the kidneys do not form this substance, but only separate it from the blood. If this were the case, however, it seems difficult to account for the fact, that not a trace of urea can be found in the blood of animals, who have not undergone this operation. Another curious fact of a similar kind is, that the blood of a frog, after the extirpation of the testicles, has been found capable of fecundating the female spawn. From the imperfect state of animal chemistry, it is probable that several principles may exist in the blood, which our present means of analysis will not enable us to detect. Dupuytren injected two ounces of bile into the veins of a dog, but the blood of the animal, which was analyzed a few moments afterwards by Thenard, exhibited not a trace of bile.*

If it could be proved, however, that all the substances of which the secreted fluids consist, preëxisted in the blood, it would not follow, that the process of secretion is a mere mechanical separation of these substances from the blood. It would still be necessary to suppose some peculiar elective power in the vessels of the secretory organs, by which the peculiar secretion of each gland should be separated from the mass of the blood, and collected in the excretory vessels of the gland. No mechanical filtration would be adequate to separate the *neurine*, or *cholesterine* from

* Le Pelletier.

the blood; or to select the numerous principles, which are formed in the urine, and to combine them together into this fluid. The process must be a chemico-vital, or dynamic one, even in the simplest case of secretion; a conclusion, which is confirmed by the fact, that secretion is so much influenced by the state of the vital or nervous power of the system at large, or of the secreting organ itself.

But with respect to much the greater part of the secreted fluids, we have no evidence that, they pre-ëxist in the blood. They cannot therefore be considered as *educts*, but must be regarded as the *products* of secretion. We must consider them as formed by the secretory vessels, out of principles furnished by the blood, which these vessels themselves have the power of selecting out of the general mass, and of combining together into new compounds. Of the nature of the process, or the means employed by the secretory vessels in accomplishing it, we are wholly in the dark. Wollaston conjectured that electricity may have some agency in secretion, an idea, which he illustrated by a very ingenious experiment. He took a glass tube, about two inches long, and three quarters of an inch in diameter, and closed one extremity with a piece of bladder. He then poured into the tube a little water, containing, in solution, a minute quantity of muriate of soda. After moistening the bladder, he placed it on a bit of silver; then bent a fine zinc wire, so that one of its extremities touched the piece of silver, and the other penetrated into the tube, to the depth of about an inch. At the same moment, the external surface of the bladder indicated the presence of pure soda. There was, therefore, from this very weak action of the electric fluid, a decomposition of the marine salt, by which the soda was separated from the acid, passed through the bladder, and was deposited on its external surface.

Dr. Young suggests an explanation of the mode in which electricity may be supposed to act, in the process of secretion. "We may imagine," he ob-

serves, "that, at the subdivision of a minute artery, a nervous filament pierces it on one side, and affords a pole positively electrical, and another opposite filament, a negative pole; then the particles of oxygen and nitrogen, contained in the blood, being most attracted by the positive point, tend towards the branch which is nearest to it, while those of the hydrogen and carbon take the opposite channel; and, that both these portions may again be subdivided, if it be required, and the fluid, thus analyzed, may be recombined into new forms, by the reunion of a certain number of each of the kinds of minute ramifications. In some cases, the apparatus may be somewhat more simple than this; in others, perhaps, much more complicated." *

The structure, or organization, by which secretion is effected, is of three kinds:—

1. The first and simplest consists merely of capillary vessels, minutely ramified. This kind of structure is employed in the separation of those fluids, which are designed to moisten and lubricate certain cavities and surfaces of the body. Thus, the pleura and peritoneum are kept moist by a serous fluid, separated from the blood by this simple kind of structure. There is some difference of opinion among anatomists, respecting the disposition and nature of these vessels. Some suppose, that they consist of the ultimate divisions of the arterial branches. Others suppose, that these vessels are pierced with a great number of lateral pores, through which the secreted fluids exude. But Bichat, and many other modern anatomists, assume the existence of a particular order of vessels, proceeding from the capillary arteries, denominated *exhalants*, of a peculiar texture and properties, and giving passage, in the healthy state only, to white or colorless fluids. These exhalant vessels are supposed to possess some peculiarities of structure and properties, in each of the different tissues of which they form a part. Hence the differences, which

* Med. Literat. p. 109.

exist in the fluids exhaled from the skin, the mucous, serous, and synovial, &c. membrane, viz. the sweat, the exhalations in the mucous cavities, the serosity, which lubricates the serous sacs, &c. The fluids exhaled by these vessels, are deposited either on surfaces, which communicate with the external air, and are eliminated from the system, in the form of a fluid or vapor,—or, in closed cavities, from which they are again taken into the system, by absorption. The fluids, thus separated by exhalation, or perspiration, from the blood, may be reduced to the following heads; 1. *cutaneous;* 2. *mucous;* 3. *serous;* 4. *synovial;* 5. *cellular;* 6. *medullary;* 7. *ocular;* 8. *vascular.*

2. Another kind of structure, one degree more complicated, is that of the *glandular follicles.* These are small, bottle-shaped sacs, lodged in the substance of the membranes in which they are situated, with their mouths opening on the surface of these membranes. Their cavities are lined by a continuation of the mucous membrane, which is supplied with a considerable number of nerves and blood-vessels. The external coat of the follicles, appears to possess a certain degree of contractility, since the expulsion of the matter secreted by them, is accomplished by the contraction of these bodies themselves. Indeed, Haller supposed that they possessed muscular fibres, analogous to those which exist in the urinary bladder. The fluid secreted in these cavities, remains some time, during which, its consistency is gradually increased, by the absorption of its more fluid parts. But, when the membrane in which they are seated, is irritated, and requires to be moistened, they contract and expel the fluid they had secreted.

Mucous follicles, or *crypts*, are found only in the membranes of relation, viz. the mucous membranes, and the skin. They open only on the free surfaces of these membranes, and this circumstance, together with the unctuous quality of the follicular secretions, sufficiently proves, that they are designed to lubricate these membranes, and to screen them, in some degree,

from the contact of foreign substances, to which, as membranes of relation, they are constantly subject. There are three kinds of fluids prepared by follicular secretion, viz. *mucus*, *sebaceous matter*, and the *cerumen* of the ears.

3. The third, and most complicated kind of structure, subservient to secretion, is that of the conglomerate glands. These are large organs, of a peculiar structure, which constitute several of the viscera. They are formed by a large number of arteries, veins, nerves, and lymphatics, disposed in a peculiar manner, and connected together by a tissue of cellular membrane. When contained in a cavity, they are invested, on their external surface, with a coat, derived from the membrane which lines the cavity; and they are provided with a canal, called the excretory duct. This duct, throughout all its ramifications in the gland, is lined with mucous membrane.

With regard to the ultimate structure of glands, anatomists have been divided in opinion. Malpighi maintained, that the parenchyma of glands is formed of hollow granules, or *acini*, each of which might be considered as a follicle, intermediate between the termination of the blood-vessels of the gland, and the origins of the excretory ducts. Ruysch, on the contrary, contended, that these acini were nothing more than inextricable plexuses of blood-vessels, and excretory ducts continuous with them, and that secretion is accomplished at the place of their communication. The opinion of Ruysch, according to Blumenbach, is much the most consistent with microscopical observations, and the effects of muriate injections. Still, some anatomists are of opinion, that some peculiar kind of structure, or parenchyma, exists in the glands intermediate between the blood-vessels and excretory ducts; and, that this parenchyma presents the peculiar and characteristic part of the organ in which its secretory function is performed; and that it varies in its structure and physiological properties, in each species of gland. Besides this fundamental

tissue of the glands, arteries, veins, lymphatics, nerves, excretory ducts, and cellular tissue, to connect the whole together, enter into the structure of these organs.

Some of the glands are provided with a reservoir, or membranous sac, in which the product of their secretion is deposited for a time, and its essential principles concentrated, by the absorption of its aqueous parts. These sacs are lined interiorly by a mucous membrane, and, externally, they are formed of a membrane, which some anatomists have considered as of a muscular nature, since it possesses the power of contracting, and thus of expelling from its cavity the secreted fluid deposited in it.

The phenomena of glandular secretion may be reduced to the four following; 1. excitation of the gland, during which the blood flows to it in increased quantity; 2. the peculiar action of the glandular parenchyma, or secretion, a chemico-vital process *sui generis;* 3. the deposit of the fluid, secreted in the reservoir of the secretion. This fluid, immediately after its secretion, is absorbed by the radicles of the excretory duct, is transmitted through this canal, by means of its insensible contractility, and deposited in the reservoir, if one exist; otherwise, it is conveyed, by the excretory duct, to the place of its destination. 4. Excretion. While the secreted fluid is detained in the receptacle, it becomes more concentrated by the absorption of its thinner parts, by which it is rendered more exciting to the walls of thiscavity; while, by its increasing accumulation, it acts as a physical stimulus. The parietes of the receptacle at length react, by their contractility, upon the secreted fluid, which is gradually forced out of the cavity; and, in some instances, certain muscles, subservient to the excretion, are excited sympathetically into action, to promote the expulsion of the secreted matter. In some cases, excretion, as well as secretion, is excited by a stimulus, acting upon the interior of the canal, into which the excretory duct opens.

The glandular secretions may be divided into the seven following kinds, viz. the *lachrymal*, *salivary*, *pancreatic*, *biliary*, *lactic*, *urinary*, and *spermatic*.

Classification of the Secreted Fluids.

The secreted fluids have been classified on different principles; 1. according to their composition, or chemical nature; 2. according to their destination, and uses, in the animal economy; 3. according to their degree of cohesion or consistency; 4. according to the structure of the organ, by which they are secreted.

I. In relation to their composition, the secreted fluids may be divided into five classes, viz.—

1. The *serous*, or watery, resembling the serum of the blood, and composed of a large proportion of water, a little albumen in solution, and salts, existing in the latter. To this class belong the serosity of the serous membranes, and of the articulations, that of the cellular tissue, of the chambers of the eye, of the capsule of the crystaline lens, and of the labyrinth of the ear.

2. The *albuminous*, distinguished by the presence of a large quantity of albumen. To this class belong the pancreatic and spermatic fluids, and the milk, which contains, besides a serous fluid, an oily matter, and several salts.

3. The *mucous*, which are characterized by the presence of a large proportion of animal mucus; as the mucus of the mucous membranes, that of the mouth, fauces, stomach, intestinal canal, nose, air-passages of the lungs, and urinary and genital organs; and, in most animals which live in the water, the fluid which lubricates the surface of the skin.

4. The *fat*, or *oily*, as the fat of the cellular tissue, the marrow of the bones, the fluid secreted by the crypts, or follicles of the skin, the cerumen of the ears, the secretion of the meibomian glands, and the sebaceous matter of the prepuce.

5. The *mixed*, as the saliva, the bile, the urine, the tears, which contain several salts, and peculiar animal principles.

II. In respect to their uses in the animal economy, the secreted fluids have been divided into two classes, viz. the *recrementitious*, and the *excrementitious;* the first, including those which are destined to be absorbed, and returned into the mass of the blood, and which are deposited in cavities which have no external outlet; the second, comprehending those which are designed, after their formation, to be expelled from the system, and which are deposited in cavities, or on surfaces, which communicate with the external air.

To the first class, or that of the recrementitious secretions, belong the exhalations into the cellular membrane, and the serous cavities; the synovial fluid, the oily fluid of the cellular tissue, and that of the round bones, and the aqueous humor of the eye. The excrementitious secretions may be divided into two orders, viz. those which, though destined to be discharged from the system, are yet designed to perform certain offices before their removal; and, secondly, such as are strictly and exclusively excrementitious, and which serve no other purpose than to depurate the blood. The first order embraces the saliva, the gastric fluid, the bile, milk, and several others. The latter comprehends the urine, and the exhalations from the skin and lungs.

Berzelius has made the interesting remark, that the secretions, or the fluids destined to be employed within the system for particular purposes, are alkaline; while the excretions, or those destined to be evacuated, are all acid. To the excretions, Berzelius refers the urine, the fluid of perspiration, and the milk. All the others belong to the class of secretions.

Thus, of the *secretions;* the bile is an alkaline fluid, containing, besides various salts, and some animal principles, a small quantity of uncombined soda. The spermatic fluid also contains about one per cent. of free soda. The tears, the saliva, and the pancreatic fluid, all contain the same alkali.

On the other hand, the excreted fluids, the urine, the matter of perspiration, and the milk, are all characterized by possessing acid properties. They all contain a free acid, which, according to Berzelius, is the *lactic*. Milk contains six parts in one thousand, of this acid, besides various salts, in some of which, it exists in a state of combination. The matter of perspiration also contains a small portion of acid, which Thenard considers as the acetic, but Berzelius conceives it to be the lactic acid. The skin, also, exhales carbonic acid. That the urine is an acid fluid, is evident from the fact, that recent human urine reddens litmus paper, an effect which, according to Berzelius, is owing to the presence of lactic and uric acids, in a free state; but, according to Dr. Prout, depends on two super-salts, which exist in the urine, viz. the superlithate, and superphosphate of ammonica.

The halitus of pulmonary exhalation, which may be regarded as one of the excretions, affords another exemplification of the principle of Berzelius. This vapor contains carbonic acid; and this, as it is generally supposed, is produced by the acidification of the carbon of the venous blood. A curious fact, first mentioned by Bichat, may be referred to the same principle. If a solution of phosphorus be injected into the veins of an animal, fumes of phosphoric acid are poured forth from the lungs, formed by the acidification of the phosphorus in the pulmonary exhalants.

Tiedemann observes, that, between the secreted and excreted fluids, there exists this difference, viz. that the former contain globules, or organic molecules, of which no traces can be discovered in the latter. Thus, globules have been found in the saliva, the pancreatic and the spermatic fluids, and the milk, which he ranks among the secretions; while none have been discovered in the urine, the bile, the tears, &c. The bile and tears, it will be observed, Tiedemann assigns to the excretions.

III. In relation to their degree of cohesion and consistency, the secreted fluids may be divided into

the *aeriform* and the *liquid*. To the first class belong the exhalations from the skin, and the organs of respiration. All the other secretions belong to the second, or that of the liquid secretions. These, however, differ exceedingly in their consistency. Some of them, as the serosity of the serous membranes, and that of the cellular tissue, the aqueous humor of the eye, and the liquor of Cotunnius, are nearly as fluid as water, though their specific gravity is greater. Next to these in cohesion, may be ranked the tears, the urine, and sweat. The saliva, the pancreatic fluid, the bile, mucus, synovia, milk, and the spermatic liquor, possess a still greater degree of consistency, and some of them are viscid and ropy. But the oily secretions, as the fat, the marrow of the bones, the cerumen, and the matter secreted by the follicles of the skin, are still more consistent, and even require a certain degree of heat to render them fluid.

IV. The secreted fluids, considered in reference to the structure of the organs by which they are prepared, may be divided into three classes, viz. the *perspiratory*, or, *the exhalations*, *the follicular*, and *the glandular*.

The perspiratory secretions, or, the exhalations, take place either in cavities which have no external opening, or on the skin, or mucous membranes. Hence, they have been divided into *exterior* and *interior* exhalations. The exterior exhalations comprehend those of the mucous membranes, and of the skin; the interior, the serous, synovial, cellular, medullary, ocular, and some others. The exterior exhalations will be considered first.

Cutaneous Exhalation, or Perspiration.

The secretion from the skin, is an albuminous halitus, or vapor, which is perpetually exhaled from its outer surface, and is termed, the insensible perspiration, though it possesses qualities which frequently

fall under the notice of the senses.* It often has a sensible odor, and frequently, instead of assuming the form of an invisible vapor, it is deposited on the skin, in drops, of a colorless liquid, which is called sweat. The instruments of this exhalation, are the numerous exhalant arteries, which enter into the texture of the skin, and open upon the surface of this membrane. The process is continually going on during life. The fluid is constantly issuing from the skin in the form of a vapor, which is immediately dissolved by the air, or absorbed by the clothing, and forms a kind of atmosphere round the body.

When condensed into a liquid, the matter of perspiration is a colorless fluid, heavier than water; and is composed of water, a small quantity of free acetic acid, hydrochlorate of soda and potash, a little phosphate of lime, a little animal matter, and carbonic acid; and, according to Thenard, a trace of oxyd of iron.† The presence of a free acid in it, is sometimes very evident, from its rank, sourish smell. The matter, with which the skin becomes incrusted, where habits of cleanliness are neglected, was analyzed by Vauquelin and Fourcroy, and found to consist almost wholly of phosphate of lime. The animal matter is the source of the peculiar odor, which distinguishes different animals, and which varies, probably, in every individual of each species. This odor is subject to many variations, from a variety of circumstances, as the age, temperament, sex, nature of the aliments, use of medicine, healthy or pathological state, &c. In jaundice, it is said that the cutaneous transpiration

* Dr. Edwards has shown, that the skin performs a function analogous to respiration; and that animals of the frog kind, will live longer deprived of their lungs, than of their skin. Under the former mutilation, they were found to live several days; in two cases out of three, thirty-three days; under the latter, or, the loss of the skin, they lived only a few hours.

† It appears, that not only carbonic acid, but azote also, is exhaled by the skin; and, according to Abernethy, in the proportion of two parts of the former, to one of the latter; and we are informed, by Collard de Martigny, that a full diet of animal food increases the proportion of azote, while a diet of vegetable food, or, of white meats, causes an increased proportion of carbonic acid.

has the odor of musk; in scrophulous persons, that of sour mucilage; in scurvy, the smell of sulphuretted hydrogen; and, in the latter stages of many fatal diseases, that of animal matter in a state of putrefaction;* characters, which might perhaps be turned to account in the diagnosis of many diseases. The peculiar odor, with which the cutaneous perspiration becomes tainted in certain diseases, is owing to the presence of certain principles, which become accidentally combined with it. Thus Orfila, according to Le Pelletier, demonstrated the presence of bile, in the sweat of patients, affected with the jaundice. The cutaneous transpiration in putrid fevers, contains, according to Deyeux and Parmentier, *ammonia*, and in milk fever, according to Berthollet, a free acid.

It is difficult to ascertain the amount of this secretion. Many experiments have been made on the subject, but with contradictory results. It is unquestionably one of the most abundant of the excretions, and some have estimated it to exceed all the rest collectively. According to Dodard, it averages in France, an ounce every hour; and bears to the solid excretions the ratio of seven to one, and to all the excretions together, that of twelve to fifteen. According to Robinson, in Scotland the cutaneous perspiration in youth bears to the urine the ratio of 1340 to 1000, or about $3\frac{1}{2}$ to 10, and in old age that of 967 to 1000. Sanvages states, that sixty ounces of ingesta, furnish five ounces of feces, twenty-two of urine, and thirty-three of cutaneous perspiration. It is much influenced in its amount by season, climate, age, manner of life, sickness, health, and probably other circumstances. Thus, in the warm months of the year, the cutaneous secretion has been found to bear to the urine, the proportion of five to three; but, in the cold months not to exceed that of two to three. In the temperate months, the two excretions have been observed to balance each other. In old age, the urinary secretion exceeds that of the skin, and the

* Le Pelletier.

reverse is true in infancy. The cutaneous exhalation exceeds the pulmonary in the ratio of about eleven to seven.

According to Lavoisier and Seguin, the greatest quantity of the insensible cutaneous perspiration is thirty-two grains a minute; equal to three ounces and two drachms and forty-eight grains an hour; and five pounds a day; its smallest amount is eleven grains a minute, or one pound, eleven and a half ounces a day. It is most abundant during digestion, and at its minimum immediately after eating. Impaired digestion is said to diminish it very much, and yet the author has known a case of very severe and obstinate dyspepsia, in which, during the process of digestion, the sweat would fall in large drops from the ends of the fingers. The average amount of the insensible exhalation is eighteen grains a minute, of which eleven are derived from the skin, and seven from the lungs. If the quantity of the insensible perspiration increases, that of the urinary and intestinal excretion diminishes. Whatever quantity of food a person may take, and whatever increase of weight he may acquire after eating, if he has attained his full growth, and is in good health, he always returns, after the expiration of twenty-four hours, to the same weight.

According to Edwards, the insensible perspiration increases after eating, during sleep, in a dry state of the air, and by exposure to heat. He also supposes atmospheric pressure to exert some influence upon it. In general, it may be stated, that it is most abundant in infancy, when it is sourish to the smell; and least so in old age. It is generally more abundant in men than in women, in whom it becomes acid during menstruation. It increases in summer, diminishes in winter, and is much more abundant in hot than in cold climates. It also varies much with the degree of excitation of the skin. When this organ is directly excited by friction, or sympathetically, from its connection with the organs, the cutaneous exhalation is much increased. When the blood contains a large proportion of water, this function frequently becomes

more active; and the same is true, when some of the other excretions are not performed with their usual activity; the defects being compensated by the increased activity of the cutaneous exhalation. The quantity of the blood is another circumstance, which influences this secretion. Plethoric persons frequently perspire copiously. Exercise, by increasing the velocity of the blood, is frequently accompanied and followed by sweating. Magendie mentions a person, who could always bring on sweating while in bed, merely by forcibly contracting his muscles for a few moments. Taking warm drink is often followed by sweating. A circumstance, which points out the influence of the nervous system upon this function, is, that certain mental emotions, as fear, and great perplexity of mind, are sometimes attended with profuse sweating.

Certain parts of the body perspire more easily and more copiously than others; as, for example, the hands and feet, the axillæ, the groins, the forehead, &c. These parts receive proportionably a greater quantity of blood than others, and some of them are secured from the contact of the air, as the axillæ and the soles of the feet. This exhalation also differs in its odor, and perhaps in its composition, in different parts of the body. Its acidity seems to be greatest in the axillæ, as appears from the red stain it frequently communicates to blue garments, under the arm-pits.

The uses of this function in the animal economy are various. It is evident, that it is subservient to the decomposition of the body. It depurates the blood of carbonic acid, and many saline ingredients, like respiration and the renal secretion, and with this last it has an intimate connection. In many animals it is the only excretion subservient to the decomposition of the organs; as no apparatus for the secretion of the urine, exists in them. Another important use of this secretion is, to absorb and carry off the excess of animal heat, and to prevent the elevation of the temperature of the body, above the natural standard. It serves also to maintain the epidermis in a state of

suppleness, favorable to the exercise of the sense of touch. Its importance in the animal economy may be estimated from the fact, that its suspension is a frequent source of disease, and its restoration, one of the most usual signs of returning health.

Mucous Exhalation or Perspiration.

The mucous membranes are the seat of an exhalation analogous to that of the skin. These membranes are the seat of two orders of secretions, one perspiratory or exhaling, the other follicular. The instruments of the first or the exhalations, are the capillary vessels, termed the mucous exhalants, which open upon the surface of these membranes, and which must be carefully distinguished from the follicles, which secrete the mucus, with which these surfaces are lubricated. The perspiratory fluid of the mucous membranes has a close analogy with the serum of the blood. It is a thin diaphanous fluid of a greater specific gravity than water, and of a slightly saline taste, consisting of muriates, and phosphates of potash and soda, albumen and a little mucus dissolved in a large quantity of water. This humor is constantly exhaled at the surfaces of the mucous membranes, which it contributes to moisten and lubricate; and perhaps aids at the same time in depurating the blood. Examples frequently occur, of a morbid increase of this secretion, as, for instance, at the commencement of nasal and pulmonary catarrhs, in which the discharge is generally thin and serous; and in serous diarrhea, and choleras, in which the quantity of serous fluid discharged is sometimes uncommonly great.

The perspiratory exhalation of the *conjunctiva*, a perfectly transparent fluid, mingles with and dilutes the tears, serves to moisten the conjunctiva, and prevent its irritation by the contact of the air, and facilitates the motion of the eye-ball, and of the palpebræ upon each other. In the serous ophthalmia, it is increased; in the dry, suppressed.

That of the nasal passage performs a similar office

in guarding the mucous membrane of the nose, from the irritating contact of the air, maintaining it in a requisite degree of moistness and suppleness for the sense of smelling, and perhaps dissolving the odorous particles, which are drawn into the nose in the act of smelling. This exhalation is frequently increased at the commencement of *coryza;* and diminished or suppressed at the invasion of an acute inflammation of the mucous membrane of the nose, and of many other acute phlegmasiæ.

The cavity of the *tympanum* is lined by a detachment of the mucous membrane of the fauces, which is also the seat of a perspiratory secretion, designed to keep the parts contained in this cavity in a condition favorable to the exercise of their functions. An increase of this exhalation produces dropsy of the tympanum; a suppression occasions a preternatural dryness of it.

The membrane which lines the interior of the *excretory ducts* of the *mammæ*, is the seat of an active exhalation, particularly during the process of lactation. It unites with and dilutes the milk secreted by the glands, and facilitates its excretion. In some cases, this membrane becomes the seat of a sanguineous discharge, vicarious of the menstrual secretion.

In the sexual and urinary organs, both male and female, the perspiratory secretion of the mucous membranes which lines them, serves to moisten these passages, and to facilitate the various functions of which they are the seats. In the female organs, this exhalation is much augmented after parturition, and takes the name of the *lochial discharge.* In chronic inflammation of the uterus or vagina, it is frequently increased, producing a discharge, terminated *fluor albus* or *leucorrhœa.* Sometimes the membrane which lines the uterus becomes the seat of a gaseous exhalation, which escapes from its cavity with an explosive noise.

The mucous membrane of the *alimentary canal*, in its whole extent, is the seat of an active exhalation, by which these passages are moistened and lubricated, their contents diluted, and their various functions

facilitated. This exhalation is much increased during the processes of mastication, deglutition, and gastric and intestinal digestion. In the stomach, the product of this exhalation is termed the gastric fluid, which is possessed of peculiar properties, and is the great agent of chymification. In certain morbid affections of the stomach, this exhalation is increased, and gives rise to vomiting or eructations of serous fluid. In the small intestines, it takes the name of the intestinal fluid, serves to dilute their contents, and probably to promote the solution of the nutritious parts, which were not digested in the stomach. A morbid increase of it, gives rise to serous diarrheas. In the large intestines, the fluid exhaled by their mucous membranes, serves to dilute the feculent matter, and to facilitate defecation. A morbid increase of it, may occasion serous diarrhea; its diminution, a hard and dry state of the feces, accompanied with obstinate constipation.

The *lungs* also, are the seat of a mucous exhalation, which keeps the pulmonary passages constantly moist, though exposed to the drying influence of the air. Like the dermoid exhalation, it assumes the form of a vapor, by absorbing a large quantity of caloric, and is probably one of the means of preventing the temperature of the lungs from rising too high, from the animal heat generated in respiration. In certain diseases of the lungs, as the humoral asthma and serous catarrh, the pulmonary exhalation is increased. The dermoid and pulmonary exhalations are probably vicarious of each other. If either is diminished, the defect may be compensated by the increased activity of the other. Thus Delaroche and Berger, having covered the whole skin with a varnish impermeable to the sweat, found that the loss of weight was not diminished, by obstructing the exhalation from the skin.

Internal Exhalations.

1. The *serous.*—The serous membranes, or those which line the serous cavities, are the seats of a con-

stant exhalation, destined to keep these membranes moist, to facilitate the gliding motions of their contiguous surfaces upon each other, and to prevent their adhesion. The exhaling vessels, which open upon the free surface of these membranes, are the sources of this exhalation. It is a transparent, colorless fluid, having a greater specific gravity than water, with little taste; and is composed of albumen, hydrochorates, subcarbonates, and subphosphates of potash and soda, and a gelatinous mucus, dissolved in a large quantity of water. It differs from the serum of the blood, according to Bostock, principally in containing a less proportion of albumen and of water. A trace of osmazome has been found in the serum of the ventricles of the brain, in hydrocephalus, and in the cephalo-spinal fluid of a horse.* A morbid increase of this exhalation gives rise to dropsies of the serous cavities. In inflammations of the serous membranes, this exhalation frequently becomes so much loaded with albumen, that it forms layers of coagulated matter over the inflamed surfaces, which sometimes become organized into false membranes, and frequently cement the contiguous surfaces together.

The cavities, in which this exhalation takes place, are those of the *arachnoides, the pleuræ, the pericardium, the peritonæum, and the tunica vaginalis.*

The *cephalo-spinal* exhalation, according to Magendie, is one of the most abundant, and most important, though least known. It is found beneath the arachnoides, covering the whole surface of the brain, filling up the depressions which this presents, and forming a layer of variable thickness, which extends from the cranium to the extremity of the sacrum. It also exists in the ventricles of the brain and cerebellum, which are lined by a prolongation of the arachnoides.

The quantity of this fluid, according to Magendie, varies with a variety of circumstances. In general, it is in the inverse ratio, to the volume of the brain. In atrophy of this organ, from old age, or any other

* Magendie.

cause, the quantity of the cerebro-spinal fluid is augmented, so as to keep the cranio-spinal cavity constantly full; and when any part of the brain is wanting, its place is occupied by this fluid. The morbid increase of it in the ventricles of the brain, constitutes the disease, termed *hydrocephalus;* its accumulation in the cerebro-spinal canal, is called *hydrorachis.*

In the cavities of the *pleuræ*, the serous exhalation serves to maintain the moisture of the free surfaces of those membranes, and to facilitate their motions upon one another, in the play of the lungs in respiration. Its morbid accumulation constitutes the disease termed *hydrothorax.*

The *pericardium*, also, is moistened by a serous exhalation, designed to facilitate the motions of the heart. Dropsy of the pericardium is the result of its morbid increase.

In the cavity of the abdomen, the exhalation from the *peritoneum* maintains the surfaces of all the organs, contained in this great cavity, in a state of humidity favorable to their free motions, and prevents adhesion between contiguous surfaces. The morbid increase of this exhalation, gives rise to one of the most frequent and most incurable forms of dropsy, *Ascites.*

The *tunica vaginalis*, also, is moistened by a serous exhalation, which, when morbidly increased, gives rise to *hydrocele.*

2. *The Synovial.*—The synovial membranes lining the movable articulations, and the sheaths of the tendons, have a close analogy with the serous membranes, and are the seat of an exhalation designed to facilitate the motions of the joints, and the play of the tendons in their sheaths. The product of this exhalation is called the synovia. It is a white or yellowish viscid fluid, having some resemblance to the white of an egg, of a slightly saline taste, and is composed of a large proportion of albumen, a fatty matter, a peculiar animal substance soluble in water, soda, muriates of soda and potash, and phosphate and carbonate of lime. Its use is to lubricate the joints, for

which purpose its smoothness and viscidity admirably adapt it, performing the same office in animal mechanics, as the oil, which we apply to those parts of artificial machines, which are exposed to friction. It is sometimes morbidly increased, giving rise to *hydrarthrosis*, or dropsy of the articulations.

3. *Cellular.*—The cellular tissue, so generally diffused throughout the system, is the seat of a double exhalation, one *serous*, the other *adipose*. The plates, of which this tissue is composed, are constantly exhaling into the cells, which they form, a fluid, which has a close analogy with that of the serous membranes, and which, probably, is subservient to the same uses, viz. to facilitate the play of these plates upon one another, and thus to favor the motions of the various organs, which are connected together by cellular tissue. In some parts of the system, where the fat might be inconvenient or injurious, we meet with the cellular tissue, wholly isolated from the adipose system; as, for example, in the cranium, the spine, the eyelids, the organs of generation, round the vessels, &c. A morbid increase of this exhalation constitutes that form of dropsy, called *anasarca*, or *œdema*.

Besides the serosity of the cellular tissue, there is found, in many parts of it, a fluid of a very different nature, called *the fat*. Magendie remarks, that some parts of the cellular tissue always contain this substance; other parts, sometimes only; and others again, never. The orbit of the eye, the soles of the feet, the pulp of the fingers, and that of the toes, *always* contain fat. The subcutaneous cellular tissue, and that which surrounds the heart, the kidneys, &c. *frequently* contain it; while that of the eyelids, the scrotum, and of the interior of the brain, are always destitute of it.

The fat is contained in distinct cells, which have no communication with those adjoining them; a circumstance which, Magendie observes, has led to the opinion, that the tissue, which secretes the fat, is different from that which exhales the serosity. The correctness of this opinion, he thinks doubtful. The

size, the form, and the disposition of these cells, are extremely variable, and the whole quantity of fat which they contain, not less so. In some individuals, it amounts to a few ounces only; in others, to some hundred pounds.

According to Chevreuil, human fat is always of a yellowish color, inodorous, lighter than water, and insoluble in this fluid; of an unctuous consistence, and becoming concrete at variable temperatures. It is very inflammable, and becomes rancid, by the action of air and light. To the microscope it presents the appearance of polyhedral granules, enveloped in a very fine diaphanous membrane. Animal fat is composed of two parts, one fluid, at common temperatures, the other concrete, composed of two proximate principles, in different proportions, termed, by Chevreuil, *elaine* and *stearine*. According to the relative proportions of these two elements, the fat is more or less fluid, at a common temperature.

The uses of this substance, in the animal economy, are chiefly of a physical kind. It lubricates the solids, and facilitates their movements. In the orbit of the eye, it forms a soft, elastic cushion, on which the eyeball moves with facility. In the soles of the feet, and on the buttocks, also, it forms a cushion, which diminishes the effect of pressure, to which these parts are so much exposed. It is also supposed to contribute to maintain the animal heat, and to guard against the effect of severe cold; since fat substances are bad conductors of caloric. The seat of the sensation of cold, however, is not the parts within the subcutaneous adipose matter, but the skin, which, of course, cannot be protected from the influence of a cold temperature, by a non-conductor, situated on its internal surface. The adipose matter under the skin, may, however, prevent the penetration of cold to the internal parts; and, in fact, corpulent persons appear to suffer less from cold, than those with lean, dry frames. In some animals, the fat forms a magazine of nutriment, to which they have recourse during the period of hybernation, being supported, during their

long winter's sleep, by the absorption of their fat. An excessive accumulation of fat is considered as a disease, and is termed *polysarcia*. The development of this substance is influenced by a variety of circumstances, as age, manner of life, diet, &c. In general, it increases after middle age, particularly in persons of sedentary habits, and those who use a full diet. The abdomen becomes prominent, the buttocks enlarge in size, and the female mammæ become more voluminous. Castration in the inferior animals, and in man, increases the disposition to the formation of this substance.

4. *Medullary.*—The cavities of the long bones, and the cells of the spongy ones, are lined by membranes, called the internal periosteum. They are the seats of an exhalation of an oily fluid, called the marrow, which fills the cavities and interstices of the bones, and which resembles the fat, adipose matter of the cellular system. The uses of it are not well known; but, by some, it is considered as a mere deposit of superfluous, nutritious matter. Haller and Blumenbach were of opinion, that its use was to render the bones more flexible. In persons who die of chronic diseases, in a state of extreme emaciation, the cavities of the bones, it is said, are found completely empty.

5. *Exhalation of the interior of the eye.*—The eyeball is formed of membranes, which inclose several humors. These humors are the product of an exhalation, of which the membranes are the seats.

The humors of the eye are the *aqueous*, secreted by a fine membrane, which lines the two chambers of the eye; the *crystaline*, secreted by the crystaline membrane, which is a closed sac, of a lenticular form; the *vitreous*, which is exhaled by a membrane of extreme delicacy and transparency, and of a cellular structure, called the *hyaloid* membrane; the black matter of the choroides; and that which lines the posterior face of the iris, both secreted by the choroides.

The first of these, or the aqueous humor, is a perfectly limpid fluid, consisting of a large proportion of water, of albumen, and some salts. It fills the two

chambers of the eye, and, if evacuated, is speedily renewed, as, for example, after the operation of cataract, by extraction.

The crystaline humor is a dense, gelatinous body, of exquisite transparency, having the form of a double convex lens. Its central parts are denser than those near the surface. It is contained in a thin capsule, and is composed of water, albumen and gelatin. It differs from the aqueous humor, in containing a larger proportion of the two latter animal principles.

The vitreous humor is a fluid, composed of albumen, gelatin, and several salts, dissolved in a large proportion of water. It is secreted by a very delicate membrane, called the *hyaloid*, in the cells of which it is contained. A morbid increase of it, constitutes the disease termed hydrophthalmia, or dropsy of the eye. The *pigmentum nigrum*, or black matter of the choroides and posterior part of the iris, is secreted by the choroid membrane. It is composed of water, gelatin, several salts, and a peculiar coloring matter.

The aqueous and vitreous humors are renewed with rapidity, when evacuated by accident, or in operations on the eye; and, according to the experiments of Leroy d'Etiole and Coiteau, it appears, that the crystaline, when extracted from the eye, is reproduced by exhalation.*

Follicular Secretions.

The follicular secretions are those, which are effected by the small secretory sacs, which have already been described, under the name of follicles, or crypts. These bodies are found only in the mucous membrane, and the skin, on the free surfaces of which they open. The viscid, or unctuous fluid, which they secrete, is designed to lubricate these membranes, and to enable them to support, without inconvenience, the habitual contact of foreign bodies, to which, as

* Magendie.

organs of relation, the skin and mucous membranes are exposed.

1. *Mucous follicular secretions.*—The mucous follicles are found in all the mucous membranes, sometimes isolated from one another, and sometimes aggregated together, in clusters. The first class, or the simple follicles, are dispersed over the palate, tongue, trachea, œsophagus, stomach, and intestinal canal. They are also found in the mucous membrane, which lines the biliary and cystic ducts, in the ureters, and bladder, and in the mucous membrane of the vagina. The conglomerated mucous follicles, are the tonsils, Peyerian glands of the intestinal canal, the prostrate gland, and the glands of Cowper.

The fluid secreted by the follicles, is termed mucus. It is a viscid, colorless, transparent, and insipid fluid, heavier than water, soluble in the acids, insoluble in alcohol, not coagulable like albumen, precipitated by acetate of lead, and becoming, by desiccation in the air, a semi-transparent, brittle solid, of a yellowish color. It is very similar, in its properties, to vegetable mucilage, but differs from it in containing azote. Bostock and Vauquelin consider it as a proximate principle; but Berzelius thinks, that it is composed of lactate of soda, combined with an animal matter. A morbid increase of this secretion, in the nasal passages, constitutes the affection termed coryza; in the lungs, bronchial catarrh; in the intestines, diarrhæa, or dysentery; in the urinary passages, blennorrhagia, &c.

2. *Cutaneous follicular secretion.*—The follicular secretion of the skin, is effected by little hollow bodies, with membranous walls, dispersed throughout the skin, and termed *sebaceous follicles.* These bodies bear a close resemblance to the crypts of the mucous membranes; but they are never clustered together, as the latter are in certain situations. They exist at the roots of the hairs, and, generally, the hairs traverse the cavities of the follicles, on their way to the surface of the skin. The fluid, secreted by them, is a thick, unctuous matter, which, diffused over the epidermis,

and the hair, serves to lubricate and soften them, to defend the skin from the effects of friction, and, perhaps, to protect it from the influence of moisture.

The number of the sebaceous follicles dispersed over the skin, is immense. Mr. Chevalier counted one hundred and forty, in the space of a quarter of an inch, which would amount to one hundred and twenty millions over the whole surface of the body. The matter, secreted by these follicles, is the vehicle of the peculiar animal odor, which emanates from certain individuals, forming an atmosphere round them, into which it is so disagreeable for others to enter.

The *meibomian glands*, or *ciliary* follicles, belong to the class of the sebaceous follicles. These are small glandular bodies, situated in the thickness of the tarsal cartilages, and secrete a peculiar sebaceous matter, which lubricates the margins of the eye-lids, and prevents the irritation, which their motions might otherwise produce. It may, perhaps, also prevent the escape of tears from between the eyelids.

The *ceruminous glands* of the ear, also, belong to the same class. They are situated in the external auditory passage, and secrete a yellow, bitter, unctuous matter, of a semi-fluid consistence, called the cerumen of the ear. The uses of it are to sheathe and protect the walls of this passage. It sometimes becomes hard and dry, by the absorption of its thinner parts, and then is a common cause of deafness, which, however, is easily relieved, by carefully removing the hardened matter.

Glandular Secretions.

Several of these have been considered already. Those, which remain to be noticed, are the *salivary*, the *lacteal*, and the *urinary;* or the secretions of saliva, of milk, and of the urine.

1. *Salivary secretion.*—The salivary glands are six in number, viz. the two *parotid*, situated in front of the ears, in the hollow between the mastoid process of the temporal bone, and the branch of the lower

jaw. These glands are composed of granulations, united into lobules and lobes, by cellular membrane. Their arteries are furnished by the carotid, the facial, and the temporal. The granulations of which they are composed, give origin to excretory ducts, which, by their union, form the *stenonian* duct, which passes across the masseter muscle, perforates the buccinator, and opens into the mouth, opposite to the middle molar tooth of the upper jaw. The portio dura, traverses the substance of this gland.

The two *submaxillary glands*.—These are situated on the inner side of the ramus of the lower jaw, between the two portions of the digastric muscle. Their ducts are termed, the ducts of Wharton, and open at the sides of the frenum linguæ.

The two *sublingual glands* are situated under the anterior part of the tongue. They are smaller than the submaxillary glands, and their excretory ducts, which are several in number, open upon the sides of the frenum linguæ.

The fluid, secreted by these glands, is termed the saliva. It is constantly flowing into the mouth, and mingles with the fluids, secreted by the membrane which lines this cavity, and by the mucous follicle. It is composed of

Water, ...	992.9
Peculiar animal matter, . .	2.9
Mucus, ...	1.4
Hydro-chlorate of potash and soda, .	1.7
Lactate of soda, and animal matter,	0.9
Free soda, ...	0.2
	1000.0

The concretions formed on the teeth, commonly called tartar, are supposed to be deposited by the saliva, as this matter is found in the greatest abundance, near the openings of the salivary ducts. It is composed of phosphate of lime, of mucus, and some animal matter.

According to Haller, from six to eight ounces of

saliva are secreted during a meal. The whole quantity secreted in twenty-four hours, has been estimated at about twelve ounces. The secretion is constantly going on, but is much more active sometimes, than at others. During sleep very little is secreted. But in eating, particularly during mastication, and in speaking, the secretion is much increased. Acids, spices, stimulants, high seasoned aliments, all promote the secretion of the saliva. The sight, and even the idea of savory food, frequently produces the same effect. Sometimes, under these excitations, the saliva is projected, in a jet, into the mouth. The action of sialagogues, especially the mercurial preparations, excites a morbid increase of this secretion, termed salivation, or ptyalism, in which, the quantity of this fluid secreted is sometimes enormous. It has, in some instances, amounted to twenty-three pounds in a day. In hydrophobia, this secretion is so much perverted, that the saliva, if introduced into the blood-vessels, becomes a most dreadful poison. Under the influence of terror or rage, also, it sometimes acquires venomous properties, causing gangrene in the part bitten by the frightened or enraged individual, or animal; and sometimes exciting a fatal affection of the nervous system, analogous to hydrophobia.

Secretion of Milk.

The organs which secrete the milk, are the *mammæ*, or breasts. These are two glands, situated on the anterior part of the thorax, below the clavicles, and before the great pectoral muscle, of a hemispherical form, covered by a smooth, delicate skin, and composed of an assemblage of lobes, each of which is formed of several lobules, and these, of acini, or granulations. The lobes are connected together by a dense cellular tissue, and are buried in a mass of fat. These acini appear to consist of minute vesicles, and an organized tissue, and they give origin to the radicles of the lactiferous ducts, which, gradually uniting, form larger trunks, corresponding in number with the lobes, and

amounting to about fifteen in each breast. These trunks do not anastomose with one another, but converge towards the centre of the gland, where they terminate in delicate excretory canals, which are collected into a bundle, and enveloped in a kind of erectile sheath. This constitutes the nipple, the small body, which projects from the centre of the mamma, surrounded by a pink-colored, or reddish brown areola. The nipple, which is of the same color, presents, on its surface, numerous fine papillæ, in which are the orifices of the lactiferous ducts. The skin of the areola and nipple, contains a number of sebaceous glands, which secrete an unctuous matter, designed to screen these parts from the saliva of the child.

The arteries of the mammæ are derived from the internal mammary, the axillary, the first intercostals, and the thoracic; its nerves, from the brachial plexus, and the intercostals. These glands are abundantly supplied with lymphatics.

The product of the secretion of the mammæ, the milk, is a fluid, of a well known color and taste; and, according to Berzelius, is composed of milk, properly so called, and cream. The milk consists of the following principles, viz.—

Water, ...	928.75
Cheese, with a trace of sugar, .	28.00
Sugar of milk, . . .	35.00
Hydro-chlorate of potash, . .	1.70
Phosphate do. . .	0.25
Lactic acid, acetate of potash, and lactate of iron, . . .	6.00
Phosphate of lime, . . .	0.30
	1000.00

Cream is composed of

Butter, ...	4.5
Cheese, ...	3.5
Whey, ...	92.0
	100.0

Whey contains 4.4 of sugar of milk and salts.

Human milk differs from that of the cow, in containing less caseum, and a much larger proportion of sugar of milk. The qualities of the milk are much influenced by the nature and quantity of the aliments. Under a diet of animal food, it is more abundant, of a thicker consistence, and less acid; while a vegetable diet diminishes the quantity of this secretion, and renders it thinner and more acid. It easily acquires the flavor and the peculiar properties of substances taken into the stomach, either as food or medicine. Hence, the disagreeable flavor which cow's milk frequently acquires, when this animal has fed upon certain kinds of plants. In like manner, purgative substances, as salts, or rhubarb, taken by the nurse, frequently operate upon the bowels of the infant. Its qualities, also, are sometimes affected by mental emotions. It has been a subject of controversy, whether the milk is secreted from the blood, or from the chyle; or, as some physiologists have supposed, from the lymph. The question seems to be decided, by the analogy of the other secretions, as well as by the fact, that mercurial injections, thrown into the mammary arteries, readily pass into the lactiferous ducts, and vice versâ. Another fact, which seems to be conclusive of the question, is, that blood is sometimes drawn into the lactiferous ducts, when the infant has completely drained the breast of milk, and yet continues to suck with force.*

Before the age of puberty, the mammæ are imperfectly developed, being small and flat; but at puberty, when the catamenia appear, they enlarge, and become prominent. Until the period of fecundation, however, they remain inactive; but, as soon as pregnancy has taken place, they begin to swell, and become affected with pricking and shooting pains. Towards the close of utero-gestation, they secrete a serous fluid, which is termed *colostrum*, and the secretion sometimes retains the same character, two or three days after

* Vesalius states, that he has seen the mammary veins, in a nurse, full of milk.

parturition. The secretion of the milk continues until the end of the period of nursing, and ceases in the course of the second year. In some rare examples, milk has been secreted by the mammæ of young virgins, and even of men.

Secretion of Urine.

The glands, which secrete the urine, are the kidneys. These are two bodies, four or five inches long, and two or three in breadth, in shape resembling the kidney-bean. They are situated on the sides of the vertebral column, before the *psoæ* and *quadrati lumborum* muscles, opposite the two last dorsal, and the two first lumbar vertebræ, imbedded in fat. The right kidney lies at the under and back part of the large lobe of the liver; the left, is situated under the posterior part of the spleen, and behind the left part of the stomach, pancreas, and colon. Sometimes one kidney is wanting, and, in some instances, there are three. They are covered, on their anterior part, by the peritoneum, reflected from the liver and the spleen.

These glands are composed of two distinct substances, an external, termed the *cortical*, and an internal, called the *tubular*. The cortical substance is about two lines in thickness, is of a lighter red, and softer consistence than the tubular, and consists, almost entirely, of blood-vessels and [acini] *granulations*, which are the commencements of the *tubuli uriniferi*. It is supposed to constitute the secretory part of the gland.

The tubular part consists of a number of conical bodies, varying from seven to twenty, with their bases directed towards the circumference, and their summits towards the centre, or pelvis, of the kidneys. The tubular part is of a darker color, and firmer consistence, than the cortical. It is composed almost wholly of convergent, uriniferous canals, which originate in the cortical substance, and which terminate in small apertures, at the summits of the cones. The orifices

of the uriniferous canals, are less numerous than the canals themselves. The rounded summits of the cones, which are perforated with the orifices of the uriniferous ducts, are termed the mamillary processes. Each of these is inclosed in a loose conical sac, termed an *infundibulum*.

The pelvis of the kidney, is a membranous sac, formed by the union of the infundibula. At its inferior part, it contracts, and is continued into the *ureter*, or excretory duct of the kidney. The ureters are long, membranous canals, about the size of a writing-quill, lined, like the pelvis of the kidney, with mucous membrane, very dilatable, and opening into the inferior and posterior surface of the bladder.

The kidneys receive their blood by the renal, or emulgent arteries, two large vessels, which spring immediately from the aorta. No other organs in the body, in proportion to their volume, receive so large a quantity of blood. A free communication exists between the renal arteries and veins, and the tubular part of the kidneys. Injections, thrown into the renal artery, pass into the veins, and into the cortical substance, and thence into the pelvis of the gland.

The renal nerves are derived from the great sympathetic.

The urinary bladder, into which the ureters open, and convey the urine from the kidneys, is a membranous sac, situated in the cavity of the pelvis, between the pelvis and the rectum. In females, it lies between the pubes and the uterus. Its posterior and upper surface is covered by the peritoneum, and is in contact with the inferior part of the small intestines.

The bladder is composed of four tunics, viz. a serous, cellular, muscular, and mucous. The serous, derived from the peritoneum, invests only the superior part of the bladder. The cellular, is situated immediately beneath the peritoneal, but is much more extensive, as it completely encircles the bladder. It is very loose, and loaded with adipose matter.

The muscular coat consists of muscular fibres,

which run in various directions over the bladder, and, by their contraction, diminish the capacity of this reservoir, and effect the evacuation of its contents. The inner coat is a mucous membrane, which is continuous with that which lines the ureters.

The bladder has three apertures, two of them being the orifices of the ureters, and the third, the mouth of the bladder, or, the commencement of the *urethra*. This last is a canal, twelve or fifteen lines long in females, and opening between the *clitoris* and the *vagina;* but, in males it is eight or nine inches in length, extending from the mouth of the bladder, to the *glans penis*. It is formed of a long fibrous membrane, lined on its interior by a mucous coat. The nerves of the bladder are derived from the hypogastric plexus.

The posterior extremity of the urethra is surrounded in three fourths of its circumference, by a collection of mucous follicles, commonly called the *prostate gland*. Before the prostate gland, there are two small glandular bodies, about the size of a pea, which open into the urethra, and which are termed *Cowper's glands*. These, together with the prostate, secrete a mucus, which passes into the urethra.

In a case mentioned by Lieutaud, the urinary bladder did not exist. The ureters, which were as large as the small intestine, opened directly into the urethra.

Secretion.—If an incision be made into the pelvis of the kidney of a living animal, the urine may be seen to exude slowly from the summits of the excretory cones. It passes thence into the pelvis, from which it enters the ureters, and from these canals it distils slowly into the bladder, gradually filling and distending this reservoir. If the uriniferous cones be slightly compressed, a considerable quantity of urine is forced out, which, however, is not limpid like the natural secretion, but thick and turbid.

The passage of the urine from the ureters into the bladder, according to Magendie, is not continual. But at short and regular intervals, the ureters, distended by the urine, open their lower orifices and suffer the

fluid to enter the bladder. The ureters then collapse and their orifices close, and the passage of the urine into the bladder ceases for several seconds, and then recommences in the same manner as before. In general, the passage of the urine into the bladder, coincides with the act of inspiration.

The urine, accumulated in the bladder, cannot ascend into the ureters, for these tubes open obliquely into the bladder, so that the pressure of the fluid, which distends it, tends to close the orifices of the ureters, and to prevent any reflux of the urine towards the kidneys. That it does not continually escape from the urethra, according to Magendie, is owing to several causes; as, the disposition of the urethra, particularly towards its vesical extremity, to maintain a contracted state; a tendency which depends on the circumstance, that the membranous part of the urethra is composed exteriorly of muscular fibres, which are endued with a strong contractile power.

But the principal cause, Magendie states to be, the action of the muscles which elevates the anus, including the *compressor urethræ* of Wilson, which, by this contraction, press the urethra upwards, keeping its parietes forcibly in contact, and thus closing its posterior orifice.

When the bladder has become distended with urine, to a certain degree, a peculiar sensation is excited in the organ, with a desire to evacuate it. The bladder is susceptible of great distension. In its natural state, it is capable of containing about two pounds of urine; but it sometimes becomes so much distended, that its fundus extends up above the umbilicus, and more than two gallons of urine have been found in it. The excretion of the urine, is accomplished by the contractile power of the bladder, assisted by the action of the abdominal muscles. The habitual disposition of the muscular coats of the bladder, to contract, is resisted by the internal extremity of the urethra. But, under the influence of the sensation which solicits the evacuation of the urine, the voluntary power excites the abdominal muscles to contract, and the action of these

muscles assists the contraction of the bladder in overcoming the resistance. The will also relaxes the muscles which elevate the anus, and which, by this contraction, close the urethra. As soon as the resistance of this canal is overcome, the urine is evacuated by the contraction of the bladder, which is generally aided by the abdominal muscles, in which case, the fluid is evacuated with a much more vehement jet. We can instantly arrest the discharge, by the voluntary contraction of the *levators* of the anus. The excretion is partly a voluntary, partly an involuntary act. The contraction of the bladder is involuntary; that of the abdominal muscles is dependent on the will. The contraction of the bladder, however, is sufficient to expel the urine; for, in experiments, in which the abdomen in living animals has been opened, and the bladder removed from the action of abdominal muscles, and even when the bladder with the prostate, and a small portion of the membranous part of the urethra, has been detached from the animal, the urine has been discharged by the action of the bladder alone. The small quantity of urine, which remains in the urethra, after the bladder has ceased to contract, is expelled by the contraction of the perineal muscles, particularly of the *bulbo-cavernosus*.

The product of the secretion of the kidneys, the *urine*, is a fluid of a yellowish color, of a peculiar, sometimes ammoniacal odor, and an acrid bitter taste. Its specific gravity is variable, being in the ratio of from one thousand and five to one thousand thirty-three, to that of water. When recent, it reddens the vegetable blue colors, but, in the act of decomposing, it changes them to a green. The first of these properties is attributed by different chemists, to the presence of various acids. Vauquelin ascribes it to the phosphoric, Thenard to the *acetic*, Berzelius to the *lactic*, Scheele to the benzoic, particularly in infants; Prout to the *superlithate*, and *superphosphate* of *ammonia*. Its powers of converting blue colors to a green, is owing to the development of ammonia, during the

decomposition of the urine. The composition of urine, according to Berzelius, is as follows, viz.

Water, ...	9.33.00
Urea, ...	30.10
Uric acid, ...	1.00
Lactic do., lactate of ammonia, and animal matter combined with them,	17.14
Mucus of the bladder, . .	0.32
Sulphate of potash, . .	3.71
Sulphate of soda, . . .	3.16
Phosphate of soda, . . .	2.94
Hydrochlorate of soda, . .	4.45
Phosphate of ammonia, . .	1.65
Hydrochlorate of ammonia, . .	1.50
Earthy matter, with a trace of fluate of lime, ...	1.00
Silex, ...	0.03
	1000.00

The principal properties of the urine are owing to the *urea*, a peculiar animal matter, which contains a large proportion of azote, and is strongly disposed to putrefaction. By the decomposition of the urea and of the mucus, ammonia is formed, which gives to decomposing urine its alkaline properties. The acid properties of recent urine, depend on the presence of the free acids, which enter into its composition. One of these, the *uric*, is frequently deposited in the form of a reddish matter, on the sides of the vessels, into which the the fluid is received. This acid, also, frequently gives rise to sabulous or calculous concretions.

The composition and the physical properties of the urine, are subject to great varieties. Under the free use of watery drinks, its quantity increases, and it becomes paler and more diluted. The proportion of uric acid increases under a full animal diet, accompanied with sedentary or inactive habits of life. The same acid diminishes in quantity, and sometimes

wholly disappears, under a diet of vegetable matter, or of substances which contain no azote, as sugar, gum, butter, oil, &c. According to Chevreuil and Magendie, the urine in dogs may be rendered at pleasure, either acid or alkaline, by confining these animals to a diet exclusively animal or vegetable. Certain coloring substances, taken into the stomach, as rhubarb and madder, communicate a deep yellow or red tinge to the urine. The same effect is produced by immersion in a bath, formed by an infusion of these substances. The urine, also, frequently becomes impregnated with the odor of certain substances, which have been eaten, or swallowed, particularly asparagus, and the turpentines.

Many substances, either introduced into the stomach, or injected into the veins, find their way to the kidneys, and may be detected in the urine. If a few grains of the nitrate or prussiate of potash, for example, be taken into the stomach, the presence of the salt may be discovered in the urine, a short time after; but, what is worthy of remark, not a trace of it can be detected in the blood. Magendie, also, ascertained that, when the prussiate of potash was injected into the veins, or was absorbed, either from the intestinal canal, or from a serous membrane, it soon found its way into the urine, where its presence might be readily detected. If the quantity of the salt injected, were considerable, its presence in the blood might be ascertained by the proper chemical tests; but, if very little were injected, it was found impossible to detect it in the blood by the usual means. The same results were obtained, when the prussiate was mixed with blood drawn from the veins; while the presence of the salt could always be detected in the urine, in whatever proportion it existed in this fluid. It appears, therefore, that substances may exist in the blood, on their route to the kidneys, without the possibility of our detecting them in this fluid; while their presence in the urine, as soon as they reach this secretion, may be readily discovered by ordinary chemical means.

The extirpation of one of the kidneys in dogs, according to Magendie, does not affect the health of the animal, but the loss of both, is inevitably fatal in a few dogs, varying from two to five. The same physiologist remarks, that, in these cases, there is an extraordinary increase of the secretion of bile, the stomach and intestines of the animal becoming filled with the fluid.

A curious fact, relating to the excision of the kidneys, which has already been mentioned, is, that after the extirpation of these glands, a considerable quantity of urea can be detected in the blood, though not a trace of it can be found in the fluid, before the experiment. The probability seems to be, that the urea preëxists in the blood, and is merely separated by the kidneys; but that, after the extirpation of these organs, as its elimentation from the blood is prevented, it accumulates in this fluid, until it amounts to a quantity, which may be recognized by chemical analysis.

Uses of the Urinary Secretion.

The secretion of the urine differs, in one respect, from all the other secretions, viz. that it is not designed for any local use. It is subservient to two general purposes, viz. the depuration of the blood, and the decomposition of the body; and, in this twofold respect, it is one of the functions most necessary to life.

Many foreign substances are constantly entering the mass of the blood, which alter the qualities of this fluid, from which it is necessary it should be regularly purified. The digestive and respiratory organs, and the great surface of the skin, are the three avenues, by which extraneous substances may enter the blood. Further, many of the secreted fluids, even the excrementitious, if any obstacle prevent their excretion, are reabsorbed and carried back into the circulation. This is the case with the bile, and milk, and probably with all the others. Even pus, the fluid of dropsies, and other morbid products, and even fecal

matter, are sometimes absorbed, and enter the mass of the blood. Now, the secretion of urine is the means, appointed by nature, to purify the blood from these and other foreign substances. Accordingly, we find the urine saffron colored in jaundice, in consequence of the admixture of bile, and of a red or deep yellow color, after the ingestion of madder or rhubarb. Many foreign substances also, which are taken into the stomach, but are incapable of chylification, soon find their way to the kidneys, and are secreted with the urine. The superfluous part of our drinks, follows the same route, and is thus discharged from the system. Foreign substances, absorbed in respiration, are in many instances discharged by the same channel. Thus the urine of a person, who breathes an atmosphere impregnated with the vapor of *ol. terebinth*, acquires a peculiar odor, which has been compared to that of violets. From the fact that the urine is the vehicle, by which these foreign matters are removed from the blood, and is in part composed of these impurities of the vital fluid, it has sometimes been aptly termed *feces sanguinis*.

Further; it is well known, that part of the materials which compose the solid structure of the body, are regularly taken up by internal absorption and carried into the circulation; and this process is as incessant as nutrition, the parts removed by absorption, making room for the fresh materials to be deposited by the nutrient vessels. Our organs are decomposed, as fast as they are recomposed or nourished, and of this decomposition, the renal secretion is an essential instrument. The peculiar principle, *urea*, contained in the urine, has been supposed to be derived from the old elements of nutrition, combined together in a peculiar mode in the blood-vessels, or, by the vital power of the kidneys.

Of the two offices of the renal secretion, which have been mentioned, the depuration of the blood, and the removal of the decomposed matter of nutrition, the first seems to be executed by a kind of filtration; for, it is found that, under certain circumstances, foreign

matters are sometimes separated from the blood by other strainers. Thus, the fluid of dropsies, sometimes manifests the qualities of the aliments which have been taken, and sometimes the presence of bile; facts, which evince that the secretory structure of the kidneys is not essential to the separation of these substances, and that they may be secreted by a simpler apparatus. So, the bones become colored red, after the use of aliments containing madder; the coloring matter, instead of being secreted from the blood by the kidneys, being deposited in the bones, with the matter of nutrition. The kidneys, however, are the organs which are particularly charged with the office of removing foreign substances from the blood; and are to the drinks, what defecation is to the solid *aliments.*

It is worthy of remark, that, after the old matter of nutrition is taken up by interstitial absorption, and conveyed into the blood, this fluid is subjected to the influence of respiration, *before* it is carried to the kidneys; and *after* being purified by respiration, and converted into arterial blood, it is transmitted to the kidneys, to be further purified, by the separation of the principles of the urine. It is a curious circumstance, that the kidneys, though depurating organs, operate upon *arterial blood*, which has, shortly before, been purified in the lungs; and this blood, when purified by the separation of the foreign matters, which may have been introduced into it, as well as of the old elements of nutrition, furnished by the *detritus* of the organs, becomes *venous blood*, which must again be subjected to the action of the lungs, before it can be employed for any other purposes in the animal economy. The blood, as it issues from the lungs, is perfectly adapted to the uses of the system; for, we find that it is immediately transmitted to all the organs, to furnish the elements of nutrition, and of the secretions, and the necessary vital excitement. Yet, we find that one-eighth of this blood is diverted into a particular channel, by which it passes to the kidneys, where it parts with certain principles, which are

noxious to it, and, if retained in the blood, are inevitably fatal in a short time. It is not very apparent why this particular portion of the arterial blood only, should be subjected to the action of the kidneys, while all the remaining, and vastly the larger part, though equally impregnated with these noxious principles, is transmitted, without this depuration, to all parts of the body. Nor is it more apparent, why, after undergoing this purification in the kidneys, and parting with these noxious ingredients, it is rendered more unfit than it was before, to administer to the wants of the economy, in being converted into venous blood, and again requiring the action of the lungs, to prepare it to subserve the uses of the system.

CHAPTER XIX.

Nutrition.

The nutritive functions, which have, so far, been considered, have all, one and the same aim, viz. that of preparing materials, which may become incorporated with the living system, and repair the losses which it is constantly sustaining, from exercise of the functions of life. Digestion, absorption, respiration, circulation, and the secretions, are only preliminary functions, subservient to *nutrition*, which may be regarded as the consummation of the assimilating functions.

That the fabric of the body is undergoing a perpetual decomposition and renovation, cannot be doubted. The immense losses, which the system is constantly sustaining from the numerous secretions and excretions, particularly from the renal and cutaneous, the

first of which contains a very large quantity of animal matter, derived, in all probability, from the *debris*, or rubbish, of the decomposing organs;—the necessity of frequent and ample supplies of aliment, and the extreme emaciation, which is the consequence of a few days' abstraction from it; the changes of volume, which the organs, and the whole body undergo, in passing through the successive periods of life, which can only be accounted for, on the supposition of an entire remoulding of the whole, from time to time, by the nutritive powers;—these, and many other considerations, leave no reasonable doubt, that the process of decomposition is perpetually going on, taking to pieces the solid fabric of the body, and that the work of nutrition follows close upon its footsteps, in repairing the losses which are thus made. A well-known experiment with madder, has usually been considered as decisive of the point, that there is a perpetual decomposition of animal matter. If this substance be mixed with the food of animals, it is found, that, in a short time, the bones of the animals become of a red color; and, if the madder be then withdrawn from their food, the red color, in a short time, wholly disappears, evidently from the absorption of the madder, which had been previously deposited in the bones. From this experiment, it has been inferred, that even the hard substance of the bones, during life, undergoes continual decomposition, and, of course, that the losses which they sustain must be repaired, by the deposition of new ossific matter; and, if this be true, that the soft solids, which have less cohesion, must probably undergo a more rapid decomposition. This experiment, however, in strict logic, proves nothing more, than that the coloring matter of madder is deposited on the bones, if the substance be taken a certain time, with the food; and that this coloring matter is afterwards absorbed, and carried out of the system. It proves, in fact, nothing more than the deposition and absorption of madder itself, and not that of the bones, or the other animal textures; and as madder is not an alimentary

substance, and is incapable of perfect assimilation, (for, otherwise, it would not communicate its color to the bones,) no inference can logically be made, from the fact of its absorption, to the absorption of the assimilated matter, of which the living solids are actually composed.

Many facts have led some physiologists to the opinion, that, while many, if not most of the solids are subject to this perpetual change of matter, there are some, which, when once formed, and fully developed, remain unalterably the same. Blumenbach is of opinion, that only those solids undergo this successive change, which possess the *reproductive* power, i. e. the property which certain parts of the bones, and nails,* and epidermis possess of repairing, not only the natural losses of matter, from the wear and tear of life, but even the removal of considerable portions of their substances from external injuries. While in those parts, whose vital powers are of a higher order, the parenchyma, which forms their base, appears to be permanent, and is liable only to this change, viz. that the interstices of the tissue, while nutrition is active, are constantly full of nutrient animal gelatine; but, when nutrition languishes, they are deprived of their gelatine, collapse, and become extenuated. This view would confine the change of matter in the body, to the parts endued with the lowest degrees of vitality, as the bones, nails, and epidermis. That the *cutis vera* is not really reproduced, and, of course, must be a stranger to this change of matter, Blumenbach remarks, is probable, from the fact, that scars are frequently permanent, and that the marks imprinted upon the skin, in the operation of tatooing, in which charcoal, ashes, soot, the juices of plants, &c. are pricked in by a pointed instrument, remain, ever afterwards.

Bourdon infers, from these facts, that there exists in the organs a fundamental tissue, which undergoes no change.

* According to Blumenbach, the nails, after the loss of the first phalanx of the finger, have been known to be reproduced on the middle phalanx.

Other physiologists are of opinion, that all parts of the body, without exception, are incessantly undergoing a renovation of their substance, by an uninterrupted movement of nutrition. The volume, the consistency, the composition, the configuration, the texture of the body, and of all its parts, the cellular tissue, membranes, vessels, nerves, muscles, cartilages, bones, tendons, ligaments, &c. all are supposed to be subject to incessant changes, more or less rapid. All animals, Tiedemann observes, live in an uninterrupted circle of formation, and transformation, of destruction, and of reconstruction.

The rapidity of this renovation of matter, in the solid parts of animals, according to the same physiologist, is in the direct ratio to the degree of complication of their structure, and the variety of their vital manifestations. Animals require larger and more frequent supplies of food, in proportion to the greater complexity of their organization, and the diversity and energy of the vital operations. The rapidity of this change of matter in the organism, is also intimately connected with the nature and number of the external impressions, to which animals are exposed. Heat, air, light, sound, electricity, food, odors, mechanical impressions, &c. act as stimulants to animals exposed to their influence, increase the energy of their vital manifestations, and occasion a more rapid exchange of the materials of their organization. The rapidity of this change, in different classes of animals, is also proportioned to the degree of development of the system of animal life, as the nervous system, the organs of sense, and those of voluntary motion.

With respect to the agents of nutrition, it is evident they can be none but the organs themselves. The function of nutrition has no separate organ, like the various secretions, and the absorbent system, to which it may be considered as opposed. Every tissue, and every organ, is the immediate instrument of its own nutrition. The materials of nutrition are contained in the blood. When this fluid, replenished with animalized matter, and depurated by the lungs

and the kidneys, is brought, in the course of the circulation, to the interior of the various organs, the nutrient capillary vessels select and secrete these principles of the blood, which are analogous to those of which the organs are severally composed, and suffer the heterogeneous principles to pass on. Thus, the nutrient vessels of the bones, secrete phosphate of lime; those of the brain the albumen of the blood, and the other elements of nervous matter; those of the muscles, the fibrin; &c. Every tissue imbibes, and, by a peculiar vital affinity, identifies with its own texture, those principles of the blood which are of the same nature with itself. But, by what mechanism the types of the various organs are preserved unaltered, in this perpetual change of the materials of which they are composed, we are wholly ignorant.

It is evident, that, as fast as the new materials are deposited in the organs, the old must be removed, by absorption, to make room for them. The physiologists of the mechanical school, supposed that the changes in the organs consisted in the *detrition*, or wearing away of their molecules, by the vital motions. While the modern chemical physiologists believe that there is a kind of *acidification*, or combustion, going on in the living organs, in which the oxygen of the arterial blood combines with the organic elements of the parts. This opinion seems to derive some confirmation from the fact, that many of the excretions contain free acids. Thus, a large quantity of carbonic acid is constantly exhaled by the respiratory organs, and the skin; and the urine, which, of all the excrementitious fluids, is much the most highly charged with the debris of the organization, contains several free acids, as the uric, the lactic, and, according to some physiologists, the acetic, and the phosphoric. This opinion is embraced, in part, by Tiedemann, who remarks, that the nature of the matters removed by excretion, appears to indicate that a peculiar process is executed in the organs, by which the organic combinations, of a higher order, or more complicated character, are converted into inferior, or more simple

combinations, and, sometimes, into inorganic ones. The complicated animal combinations, formed by the powers of assimilation, from the materials received into the system from without, are decomposed by the vital action of the organs, and converted into organic combinations of the lowest class, and sometimes even such as are inorganic; and this process, Tiedemann supposes to be analogous to combustion. The formation of inorganic acids, in the excreted fluids, has already been noticed. Besides these, may be mentioned certain principles which exist in the bile, as the biliary resin, and cholestine, two ternary compounds, which may be considered as organic combinations of the lowest class, and which are evacuated by the alimentary canal. The urine, also, contains organic principles, which may be referred to the same class as the urea, and the uric acid, besides many inorganic compounds, consisting of a great number of different salts. Tiedemann refers to this process the production of animal heat, which, he remarks, is exactly proportioned in animals, to the rapidity with which the materials of the organization are renewed.

Some physiologists have supposed, that there is only one kind of nutritive matter, and that, out of it all the organs are nourished. The different chemical composition of the organs, however, seems to be inconsistent with the unity, or identity, of the matter of nutrition. How, for example, can the albumen of the brain, the gelatin of the tendons, the fibrin of the muscles, the calcareous phosphate of the bones, the fat of the cellular tissue, be derived from one and the same nutritive matter? It is enough to suppose that the arterial blood, which is conveyed to every organ, contains, in itself, all the nutritive principles, which are necessary to the renovation of the organs; and that, out of this apparently homogeneous fluid, the nutrient vessels of each tissue select, by a peculiar vital affinity, such as are homogeneous to the nature of the tissue, as in the case of the other secretions.

Nutrition seems to be dependent, in some measure, though how far it is difficult to determine, upon the nervous influence. A limb, which has become paralytic, by a section, or compression, or any morbid affection of the nerves distributed to it, in some instances, preserves its original volume; a fact, which proves, that its powers of nutrition are unimpaired by the loss of the nervous influence. More generally, however, it becomes dry and withered, and sensibly diminished in volume; an effect, which may, perhaps, be attributed, in part, to the want of exercise of the paralyzed part. A fact, mentioned by Magendie, appears to prove, that nutrition is, to a certain extent, influenced by innervation. He found, that when the fifth nerve is divided, in the cavity of the cranium of a rabbit, close to its apparent origin, the surface of the eye inflames at its upper part, and the superior segment of the cornea becomes clouded. And if the fifth nerve be destroyed upon the petrous portion of the temporal bone, where its destruction involves that of the Gasserian ganglion, the whole cornea becomes opaque in twenty-four hours; and, the next day, the conjunctiva and the iris inflame, the crystaline lens and the vitreous humor begin to lose their transparency, and soon become entirely opaque, and, in eight days after the section of the nerve, the cornea detaches itself from the sclerotica, and the humors of the eye are discharged by the aperture. The nutrition of the eye, then, according to Magendie, is evidently subject to the nervous influence.

The division of the *par vagum* in animals, also, gives rise to inflammation of the stomach, if the operation is not fatal in less than three or four days; a fact, which, perhaps, may be referred to the same cause.

CHAPTER XX.

Animal Heat.

Calorification is a function, so intimately connected with nutrition, that it may not improperly be considered in this place.

Before the discovery of the composition of the atmosphere, of the formation of carbonic acid, and of the nature of combustion, the origin of animal heat was a subject on which a good deal of fruitless speculation was lavished; and, as is often the case, where reasoning is substituted for experiment and observation, the consequence was a wider departure from truth, than the first crude conceptions of the earliest observers. It is a little curious, that Galen was struck with the analogy between respiration and combustion, since he compares the lungs to the wick of a lamp, though he was not aware of all the points in which the analogy holds. In modern times, previous to the discoveries in pneumatic chemistry, the production of animal heat was ascribed to a variety of insignificant causes, especially attrition, or the friction of the blood against the sides of the vessels. Some physiologists supposed that heat was an essential property of life, that the principal focus of animal heat was the heart, and that the chief office of respiration was to *cool* the blood; an idea well expressed by the phrase, *ventilation of the blood*, adopted by Dr. Good.

The discovery, by Black and others, of the production of carbonic acid, both in respiration, and in the combustion of vegetable substances, first brought to light the real analogy which exists between these two processes; and they led Black and his followers to the opinion, that respiration is, in fact, a species of combustion, in which a sufficient quantity of heat is

developed in the lungs, to preserve the temperature of the animal, at the requisite elevation, above that of the surrounding element. A difficulty, which encumbers Black's hypothesis, is, that it leaves unexplained the fact, that the temperature of the other parts of the body is as great as that of the lungs; whereas, if these organs are the great focus of animal heat, the place where it is first developed, and whence it is diffused to other parts of the system, their temperature, we should expect, would be much higher than that of other parts of the body. This doctrine, however, was adopted, in substance, by Lavoisier and his followers.

A very important modification of this opinion was proposed by Crawford, no less remarkable for its ingenuity, than for the happy explanation it furnishes of the difficulty which encumbered the hypothesis of Black and Lavoisier. Crawford assumed, as they had done, that respiration is a species of combustion, in which, the air inhaled into the lungs undergoes the same change as by the combustion of substances containing carbon, and that heat is generated in precisely the same manner. But he attempted to establish the fact, that the arterial blood, into which venous blood is converted, by respiration, possesses a greater capacity for caloric, than venous blood; and that the heat, generated in the lungs by the combination of oxygen and carbon, does not increase the temperature of the lungs, but is immediately absorbed, and becomes latent in saturating the increased capacity of arterial blood. Hence, though heat is generated by respiration, yet it is not actually disengaged, or rendered sensible in the lungs, but is absorbed, and becomes latent, in the arterial blood, and is gradually developed, in the course of the circulation, as the blood loses its arterial, and assumes the venous character; for the venous blood, having a less capacity for heat than arterial, i. e. requiring less caloric to preserve it at the same temperature, will have its temperature raised by the gradual development of the excess, while it is assuming the venous properties.

Unfortunately for this beautiful theory of Crawford, the position, which forms the corner-stone of the whole, viz., that arterial blood possesses a much greater capacity for caloric, than venous, has been disproved by Dr. John Davy, who maintains, from his own experiments, that there is little or no difference between the capacity of arterial or venous blood.

Another theory of animal heat is that of Mr. Brodie, who infers from experiment, that the production of animal heat is not a result of respiration, but depends on the nervous influence. His experiment consisted in decapitating an animal, and keeping up respiration artificially, by inflating the lungs. He found that the usual changes in the blood were effected by this artificial respiration, without the aid of the nervous system; for the venous blood assumed the arterial color, and carbonic acid was formed exactly as in natural respiration. But, notwithstanding the usual changes took place in the blood, and in the air introduced into the lungs, the generation of animal heat was suspended, and the temperature fell with greater rapidity than in another animal killed at the same time, in which artificial respiration was not practised. This experiment, however, is not absolutely conclusive. Dr. Philip discovered that the cooling of the animal was owing to the circumstance, that *too much air* was forced into the lungs. He found that, if a less quantity were introduced, the cooling process was sensibly retarded; and, in one experiment, he succeeded in raising the temperature nearly one degree. At the present day many physiologists are disposed to transfer, from the lungs to the capillary system, the function of generating animal heat. The production of this principle, seems to be universally connected with the action of the vital forces, and to follow all the vicissitudes by which these are affected. Hence it happens, that heat is always increased by the energetic and prolonged action of any organ whatever, as well as by any morbid excitement; that it is subject to frequent variations, being increased in some parts, and diminished in others. The head becomes

hotter in deep thinking, an inflamed part is hotter than the neighboring parts, a draught of wine excites a feeling of heat in the stomach, &c.; facts, which appear to prove, that it is in the capillary vessels, that the production of animal heat takes place. It is not easy to determine the nature of the vital actions in these vessels, by which caloric is evolved. But it seems not improbable, that it is the changes of combination of the molecules of the fluids and solids of the body, in the processes of nutrition, secretion, digestion, hematosis, &c., that we are to seek for the source of the animal heat, disengaged in the capillary vessels. This supposition will account for the variable states of calorification, under various circumstances of the system, as the energy of the function would then be regulated by the degree of activity of nutrition, secretion, &c., which processes are constantly varying in their energy and excitement.

Now, two conditions are necessary to the functions of the capillary vessels, and, consequently, if the last mentioned view be correct, to the production of animal heat; one, the presence of arterial blood; the other, the action of the nervous system. The vital processes, which are executed by the capillary vessels, require the aid of the nervous influence, and the presence of arterial blood. If a part be deprived of arterial blood, or, be cut off from all communication with the great nervous centres, its nutrition languishes, and its temperature falls. Two conditions, also, are necessary to the presence of arterial blood in a part, as well as in the whole system; one is the function of respiration to form it; the other, the circulation to distribute it. Hence it follows, that three conditions are favorable to the production of animal heat; a respiratory apparatus, a developed circulating system, and the nervous influence, coöperating together in producing energetic vital actions. Calorification is not dependent on either exclusively, but is the result of the whole.

Of these three functions, however, respiration seems to claim the largest share in the production of animal

heat. The connection of calorification with this function, cannot be mistaken. Every thing which increases the activity of respiration, the consumption of oxygen, and the production of carbonic acid, as animal food, wine and exercise, increases the heat of the body. Whenever, on the contrary, respiration is imperfect, as in Asthma, the temperature of the body is lower than natural. Animals, which possess a highly developed respiratory apparatus, and consume a great deal of oxygen, have a higher temperature than those, which are less favorably endowed in this respect. Thus birds, which consume much oxygen, have a blood warmer, by several degrees, than the human species. In cold-blooded animals, on the contrary, which use but little oxygen, and are able to live a long time without breathing, and in the reptiles, in which respiration is very imperfect, and only a part of the blood is transmitted through the lungs, the temperature is very low. So, animals in a torpid state, in which respiration is suspended, are quite cold. In general, the activity of respiration is a pretty good criterion of the energy of calorification. According to Magendie, it seems to be demonstrated, that respiration produces four-fifths of the heat in herbivorous animals; and three-fourths in carnivorous; and about the same proportion in birds. The development of heat by respiration, Magendie supposes to be owing to the formation of carbonic acid, whether this takes place in the lungs themselves by the union of oxygen of the air, and the carbon of the blood, or, in the course of circulation, or, even in the parenchyma of the organs. The temperature of arterial blood is higher than that of venous. Holland remarks, that it has been proved, by direct experiment, that the blood acquires at least one degree of heat in passing through the lungs; and as it is computed, that the whole mass of the blood passes through the lungs twenty times an hour, it follows, that the system receives, from respiration, twenty degrees of heat in an hour, or two hundred and forty degrees every twelve hours. Holland con-

siders the lungs as the only source of animal heat; and Magendie, as the principal one.

The influence of the nervous system on calorification, is also evinced by many facts and experiments. Brodie's experiments have already been noticed. Great lesions of the nervous system are found to diminish the production of animal heat. Chaussat divided the brain, anterior to the pons varolii, leaving of course the par vagum uninjured. The circulation was not affected by the experiment, and Chaussat observed, that arterial blood circulated in the arteries. Yet, in twelve hours the temperature sunk from one hundred and four degrees to seventy-six degrees, Fahrenheit, when the animal died. Heat appeared to be no longer evolved from the moment of the section of the brain. So, when the brain was paralyzed by a violent concussion, or, a strong infusion of opium was injected into the jugular vein, and respiration was maintained artificially, the result was the same. The par vagum was divided in a dog, and artificial respiration was practised; but the heat began to fall, and death at length took place. The blood was arterialized, and the animal died, not of asphyxia, but of cold. In another experiment, the spinal marrow was divided below the occiput, and respiration kept up by inflating the lungs; but the heat fell, and in ten hours the animal died from cold. The division of the spinal cord lower down, was followed by the same result. In these experiments, however, it is probable, that the reduction of the temperature was owing, in part, to the introduction of cold air into the lungs. Concussions of the brain are followed by great coldness of the body. Morbid affections of the nervous system, also, frequently occasion a sensation of cold, and an actual reduction of the animal heat. The temperature of a paralyzed limb, is generally less than that of a sound one. These facts prove, that the generation of animal heat is, in some measure, influenced by innervation; but, whether directly or not, is not apparent. The capillary circulation, and probably all the

functions executed by the capillary vessels, are influenced by the nervous system; and if so, it is not improbable, that the influence of this system upon calorification is not immediate, but is exerted through its action upon the capillary circulation in the lungs, and the general system. Holland is of opinion, that the nervous system has no influence whatever upon the generation of animal heat, except in diminishing or retarding these chemical changes on which it depends, by destroying the natural proportions of blood submitted to the action of the air.

That calorification is influenced by the state of the circulation, appears from the fact, that a depressed state of this function is attended with a diminished, and an excited, with an increased temperature of the system. In certain malformations of the heart also, as those in which a communication exists between the right and the left cavities, the temperature of the body is below the natural standard.

CHAPTER XXI.

Functions of Relation.

The third class of functions embraces those of relation, or the physiological actions, by means of which animated beings, and particularly man, are enabled to maintain a communication with the external world. It includes, 1. those functions by which we receive impressions from external objects, or from the play of our own organs, which, in relation to the sentient principle, may be considered as external; 2. those by which we variously combine, decompose, and recombine, the sensations resulting from these impressions

by an intellectual elaboration, and derive from them the materials or occasions of many internal perceptions, judgments, and feelings, and volitions, which, however, cannot be analyzed into them; and, 3. those by which we give expression to our feelings, judgments and volitions, by certain sensible signs, which are produced by the action of certain organs, endued with the power of voluntary contraction; and by which we, in our turn, react upon the external world. The first order of these functions embraces those of *sensation;* the second, those of *perception*, of the *intellect*, and of the *moral sense;* the third, those of *voluntary action.*

Sensation.

By sensation is meant those physiological actions, by which man and other animals, receive and become conscious of various impressions made upon them by external objects, or by the actions of their own organs.

Sensations are divided into two classes, *external* and *internal.* External sensations are those, which result from the action of certain external causes, upon the organs of sense; the internal are those which originate in the system itself.

The first, or the external sensations, are the commencement of the functions of relation. They apprise us of the nature and qualities of the external objects, with which we are surrounded, and are necessarily in constant intercourse; enable us to observe and distinguish them, and to seek such as may be useful, and to avoid those which are hurtful to us. The second, or the internal sensations, apprise us of the wants or the condition of our own systems.

External sensation is of two kinds, viz.: general and special. General or *tactile*, gives us a knowledge of the common qualities of natural objects, as form, dimensions, consistency, weight, &c.; the special inform us of certain other qualities of a more specific

and peculiar character, as their color, taste, smell, &c.

The organs of sensation consist of the common integument of the body, viz.: the skin, or of certain pieces of structure curiously organized, and designed to collect and to modify the impressions received from external objects; and of expansions of nervous matter, disposed in such a manner as to receive these modified impressions. These organs are situated at some part of the periphery of the body, and have a direct communication with the brain or spinal cord, by means of nerves.

CHAPTER XXII.

Sense of Touch.

This sense differs from all the others, in the circumstance that it has no peculiar or specific excitant, and that its exercise is not confined to any particular organ, though it belongs in a special manner to the hand, and especially the tips of the fingers, and that it does not require any peculiar or specific sensibility, but only the common powers of sensation, which are diffused over the whole surface of the body. We acquire ideas of most of the physical properties of bodies, by means of this sense; as their form, dimensions, weight, temperature, smoothness, roughness, degrees of consistence, distance, motions, &c.

The skin, the structure of which has already been described, is the general organ of touch. The immediate seat of the sense is the papillæ of the *cutis vera*, or *corium*, which are minute prominent bodies of various forms, disposed over the external face of the

corium. According to Magendie, they appear to be essentially vascular, and when destroyed, are reproduced. They are very sensible; and in them terminate the extremities of all the cutaneous nerves.* The epidermis is perforated, opposite the summits of these bodies, with minute orifices, from which escape little drops of sweat, when the skin is exposed to an elevated temperature.

The exercise of this sense is favored by several circumstances, as the thinness and delicacy of the cuticle, warmth, and a free cutaneous transpiration.

The nerves, which are subservient to the sense of touch, are the posterior roots of the spinal nerves, the large division of the fifth, the par vagum, and the glosso-pharyngeal.† The spinal nerves are distributed to the body, neck, occiput, and the limbs; the fifth pair to the face, temples and fauces; the par vagum and the glosso-pharyngeal, to the pharynx, and œsophagus. The nerves of touch are provided with ganglions near their origins.

Different parts of the skin are endued with this sense, in different degrees. The hands, and particularly the ends of the fingers, enjoy the most delicate sense of touch. In the hands, the skin possesses some peculiarities, which adapt it more perfectly for this office. The epidermis is thin and delicate; the transpiration copious, and the vascular *papillæ* more numerous than in any other place. The corium receives a very large supply of blood-vessels and nerves. Further, in the palms of the hands, and on each side of the joints of the fingers, the skin is furrowed to facilitate the closing of the hands, and thus enable them to grasp the objects submitted to their examination. The motions of the hands, also, are easy and very various; so that the organ can apply itself to all parts of

* Magendie remarks, that the corium receives a great number of nerves, particularly in those parts of the membrane, which are most concerned in *touch;* but he says, that we are wholly ignorant of the manner in which the nerves terminate in the skin, and that all which has been said of the *nervous papillæ* of the skin, is hypothetical.

† Mayo.

the bodies it examines, whatever may be the irregularities of their shape. The tips of the fingers, also, are furrowed on their palmar side, by delicate spiral lines; and externally, are supported by horny scutiform appendages, the nails; which are found only in man, and the quadrumanous mammalia.

Besides the hands and feet, the whole surface of the body possesses the sense of touch; and even the mucous surfaces of the eyes, nose, and fauces, larynx, pharynx, and œsophagus, the rectum, and urinary canal. The voluntary muscles, also, appear to enjoy a peculiar kind of touch, owing, as Mayo supposes, to the circumstance, that branches of the same sentient nerves, which supply the skin, are distributed to the voluntary muscles, in conjunction with the nerves subservient to voluntary motion.

Touch is either active or passive. Active touch is exercised chiefly by the hands. In the exercise of this sense, we apply our hands to the object to be examined, either grasping it with them, or passing the palmar sides of the fingers, particularly their tips, successively over its surface. The motion of the hands or fingers, is indispensable to the active exercise of this sense. If one hand merely remain in passive, motionless contact with the surface of the body, we receive only very obscure and imperfect sensations, similar to those, excited by the contact of the substances with any other part of the surface of our bodies. In order to acquire ideas of the form, dimensions, consistency, &c. of objects, it is not enough that they be placed in contact with our hand; we *must apply our hands to them*, and pass our fingers successively over different parts of their surface, and exert an act of attention to the sensations which we receive. During this tactile exploration of bodies, the papillæ of the fingers experience a kind of *erection*, by which their receptivity is increased, or they are rendered more sensible to the impressions made upon them. It is by this active touch, that we get our ideas of most of the tactual properties of bodies, as their shape, size, hardness or softness, smoothness, roughness, &c.

By the passive sense of touch, we derive our sensations of the temperature of bodies, and vague and imperfect ones of their other physical qualities. We receive, also, impressions of various kinds, from the chemical and mechanical properties of substances, applied to our bodies. Thus, substances, which exert a chemical or corrosive action upon the skin, as the caustic alkalies, strong acids, &c. excite peculiar painful sensations, by which the actions of these substances may be distinguished. So, the application of pointed or cutting bodies to the skin, excites painful sensations of a peculiar kind. We can, also, feel the *weight* of heavy substances, placed upon any part of our bodies, though we cannot so well *appreciate* it, as by the resistance it opposes to voluntary muscular contraction.

The resistance to our muscular efforts, which material bodies present, is supposed to be the source of our ideas of hardness, and softness, weight, and of some other physical qualities, which we combine into the idea of matter. It is certain, however, that we receive very distinct impressions of hardness from the application of hard substances to parts which are not muscular; as, for example, the teeth, the head, the ribs. Hard bodies, impinging upon these parts, excite as strong and distinct idea of hardness as it is possible for us to acquire from any degree of resistance to our muscular efforts.

The mucous membranes possess a very delicate sense of touch. This is particularly the case with that which lines the lips, the tongue, the larynx, the nasal passage, the urethra and the vagina. The conjunctive of the eye is, also, endued with great sensibility. The contact of foreign bodies with any of these surfaces, is always painful at first; but, at length, it ceases to be so, or becomes indifferent by the power of habit.

No one of the senses is susceptible of greater improvement by exercise, than that of touch; a fact, which is strikingly illustrated by the exquisite delicacy of this sense, which is acquired by the blind.

Most of the organs and soft solids of the body, like

the skin, possess the faculty of transmitting impressions to the brain, when they are exposed to the contact of foreign bodies, or to any kind of mechanical violence.

The bones, tendons, cartilages, ligaments, and fasciæ form an exception to this general fact; since, in a healthy state, they are invisible, and may be divided, burned, or lacerated, without giving notice to the mind, by any painful sensation.* The ligaments, however, become affected with most acute pain, when subjected to mechanical violence of a certain kind, as that of wrenching. It is a remarkable fact, that several of the nerves are insensible to mechanical irritation. This, according to Magendie, is the fact with the first, second, third, fourth, sixth, the portio mollis of the seventh, and the branches and ganglions of the sympathetic.

CHAPTER XXIII.

Vision.

The apparatus of vision consists of the eyes, and their appendages. The eyes are two moveable globes, lodged in deep sockets, in the upper and anterior part of the head, on the right and left of the root of the nose.

They are composed of various parts, which perform different offices in the complex function of vision.

The eye is a dioptric instrument, constructed with admirable skill, and designed to refract the rays of light, which enter the organ from luminous objects, in

* Magendie.

such a manner, as to form images of them at the bottom of the eye. These images are painted, bottom upwards, on a nervous membrane, called the retina, which is considered as an expansion of the optic nerve, and is the immediate seat of vision.

The globe of the eye has the form of a spheroid, of which the antero-posterior diameter is the greatest, and, in the adult, is ten or twelve lines in length. It is composed of various coats, or tunics, inclosing humors of exquisite transparency, and of different degrees of density. The tunics of the eye are four in number, and are severally termed, the *sclerotica*, *the cornea*, *the choroides*, and *the retina*. The humors contained in them, and which constitute the principal part of the bulk of the eye-ball, are three in number, viz. the *aqueous*, the *crystaline lens*, and the *vitreous*.

The external coat of the globe of the eye, is the *sclerotica*, which is a strong, fibrous, opake membrane, evidently designed to protect the internal parts of the eye, and to serve as a place of insertion to the muscles, which move the eye-ball. As this membrane is opake, it is of course incapable of transmitting light to the internal parts of the eye. But, in the centre of its anterior part, it has a circular aperture, like a window, which is filled by a transparent lamellated membrane, presenting a convex surface anteriorly. This membrane is called the *cornea*. It is the segment of a smaller sphere than the sclerotica, into which it is inserted, something like a watch crystal, and, of course, projects from it. It is ingeniously termed, by Arnott, the *bow-window* of the eye. The cornea is thicker than the sclerotica, and is formed of six distinct laminæ, easily separated from one another, and the internals of which contain a limpid fluid. This fluid transudes after death, leaving the cornea opake, and tarnished, and evidently flattened. No nerves, nor blood-vessels, can be discovered in the cornea.

Next to the sclerotica, and lining its internal surface, to which it is connected by vessels, nerves, and a cellular tissue, is the *choroid*, or vascular coat of the

eye. This extends, posteriorly, as far as the opening, through which the optic nerve enters the eye, and forward, to the ciliary circle. Its inner surface is contiguous to the retina, without, however, adhering to this membrane. The choroid coat seems to be almost wholly composed of a multitude of arteries and veins, connected together by a very delicate cellular tissue. It is covered, on both surfaces, by a kind of black varnish, called the *pigmentum nigrum*, secreted from its vessels, the use of which is supposed to be, to absorb the superabundant rays of light, and thus to temper its intensity. Some anatomists have considered the choroides as a prolongation of the *pia mater*, which forms the neurileme of the optic nerve.

Anteriorly, the choroides is bounded by a ring, or belt, of cellular or nervous matter, of a pulpy consistence, called the *ciliary circle*, or *zone*. This gives origin to a great number of loose folds, radiating round the crystaline lens, called the *ciliary processes*. The number of these processes varies from sixty to eighty.

Next to the choroid coat, and expanded over its inner surface, is a soft, pulpy, transparent membrane, termed the *retina*, on which are distributed the fibrillæ of the optic nerve. It has generally been considered as an expansion of this nerve, but, perhaps, erroneously. The retina is the most interior of the tunics of the eye-ball, and immediately embraces the vitreous humor. It is the most important part of the eye, being the immediate seat of vision.

In the anterior part of the globe of the eye, behind the transparent cornea, and conspicuously visible through it, is a circular membrane, placed perpendicularly, and perforated with a round opening, called the pupil of the eye. The circular curtain itself is the *iris*. Its anterior surface is differently colored in different individuals; its posterior, like the choroid coat, is covered with a black varnish. The size of the pupil is determined by the motions of the iris.

The humors of the eye, whose office it is to refract the rays of light, are three, viz. the *aqueous*, the *crys-*

taline, and the *vitreous*. The vitreous, so called, from its resemblance to melted glass, fills the posterior part of the globe of the eye, and constitutes by far the largest portion of the eye-ball. This humor is dispersed through innumerable cells, formed by a membrane of exquisite delicacy and transparency, and has the appearance of a tremulous jelly. The vitreous humor, occupying three-fourths of the cavity of the eye-ball, is of a spherical figure, with a depression in front, in which is lodged the crystaline lens. This is a small lenticular body, of the most perfect transparency, and convex on both surfaces. Its posterior convexity is greater than its anterior; i. e. it is the segment of a smaller sphere. The crystaline lens is much more dense than the vitreous humor, and is the most important of the refracting powers of the eye. It is composed of concentric laminæ, of which, the central ones are more compact and solid than the exterior, or cortical layers, and form a kind of solid nucleus, on which the former are superimposed. The crystaline lens contains a large proportion of albumen, in consequence of which, it loses its transparency, by the action of a certain degree of heat, as that of boiling water, by acids and alcohol. A similar change sometimes takes place spontaneously, and constitutes the disease termed *cataract*.

The crystaline lens is invested by a membrane, called the *capsule* of the crystaline. Between this membrane and the lens, a small quantity of transparent fluid is found, which is called the *liquor of Morgagni*, and which immediately escapes when the capsule is opened. The capsule is covered anteriorly by a lamina of the hyaloid membrane of the vitreous humor. For, near the circumference of the lens, this membrane separates into two laminæ, one of which, passes before the lens, as just described; the other, behind it, lining the cavity in the vitreous humor, which receives the lens. By this separation of the laminæ of this membrane, a small triangular canal is formed, at the circumference of the crystaline lens, called the *canal of Petit*.

The remaining, and anterior part of the eye-ball is occupied by a limpid fluid, called the *aqueous humor;* which fills the space between the cornea and the crystaline lens. This space is divided, by the iris, into two unequal parts, called the *anterior* and *posterior chambers* of the eye, which communicate freely with each other, by means of the pupil. Both surfaces of the iris are, of course, bathed by the aqueous humor. The quantity of this humor amounts to five or six grains. It is secreted by a very delicate membrane, which lines the parietes of the anterior chamber of the eye, and is readily renewed, if any cause occasions its evacuation from the eye. This membrane is perforated by the pupil of the eye; but, in the fetal state, until about the seventh month, it forms a serous sac, without opening, extending over the pupil, so as to isolate the two chambers from each other. The temporary part, which closes the pupil, is called the pupillary membrane. It is usually ruptured, and disappears about the seventh month of gestation, and sometimes earlier. Its persistence, after birth, is said to be one cause of blindness. The aqueous humor consists of water, holding in solution a minute quantity of saline and animal matter. In jaundice, it sometimes becomes impregnated with bile, which gives it a yellow tinge.

Muscles of the eye.—The eye-ball is moved by six muscles, which are attached, posteriorly, to the bottom of the orbit, and, anteriorly, are lost in the sclerotica. Four of these muscles are called *recti*, or straight; and the remaining two, *obliqui*, or oblique muscles. A particular description of their situation and uses, belongs to anatomy.

Nerves of the eye.—The eye is abundantly supplied with accessory nerves, from different sources, besides receiving the whole of the optic, which is the proper nerve of vision. The optic nerves are of considerable volume, in proportion to the size of the eye. They are said to originate from the anterior part of the *tubercula quadrigemina*, and not, as was formerly supposed, from the *optic thalami*. Rudolphi, however,

regards this opinion as incorrect; and, in confirmation of his own views, he mentions, that he had examined the brain of a child, in whom, the right eye, and its orbit, were wanting; while the left was perfectly formed. On dissection, he found the tubercula quadrigemina perfectly alike, on the two sides; while the right thalamus of the optic nerves, was abnormal, both in size and situation; the left, alone presenting the natural characters. From this case, he infers that the optic nerves do not originate from the tubercula quadrigemina, though he does not deny, that a connection may exist between the latter and the origin of these nerves. In their passage to the orbits, the optic nerves approach each other, and unite together at the *sella Turcica*, from which point they again separate and diverge, each passing into the corresponding eye, through the *foramen opticum* of the *sphenoid bone*. The nerve does not enter the eye exactly in its axis, but a little nearer the nose. It is invested with a coat, derived from the dura and the pia mater. It has been a subject of much dispute, whether the optic nerves, at their union on the *sella Turcica*, are in the relation of mere juxtaposition, or whether they do not, completely or partially, decussate each other. Various opinions, supported by more or less evidence, have been entertained on this subject. Galen and Vesalius held to the juxtaposition of the optic nerves; the former, from having met with a case of atrophy of the eye, and of the optic nerve, on the same side; the latter, from a remarkable case, in which the two nerves remained separate through their whole course.

Other facts, equally conclusive, favor the opinion of the complete decussation of these two nerves. Thus, Sœmmering found, in seven persons, blind of one eye, that the atrophy of the nerve was on the side *opposite* to that of the affected eye. Richerand and Portal observed blindness of one eye, occasioned by apoplexy, seated in the opposite hemisphere of the brain. Meckel cites cases of complete separation of the optic nerves, through their whole course, from Nicolaus de

Janua and Valverde.* A perfect decussation of the optic nerves, without their even adhering together, occurs in fishes, with a bony skeleton, with the single exception, according to Rudolphi, of the *gadus morhua*, or cod-fish. Magendie found, that when the optic nerve of one side was divided behind the commissure, the eye of the opposite side, was affected with atrophy; and when one eye was destroyed, the nerve of the opposite side, behind the commissure, withered. Upon destroying the union of the two nerves, by an incision made at their junction, the sight of both eyes was abolished; an effect, which appears to establish the complete decussation of these nerves.

Other physiologists contend for the partial decussation of the optic nerves, asserting that only some of the filaments, on the internal side of the two nerves, cross each other; so that each nerve, anterior to the *chiasma*, is formed partly of filaments, derived from the nerve of the opposite side, and partly of those which primitively belonged to it. This opinion was embraced by Wollaston, as affording an explanation of the affection of vision, called *hemiopia*.

Berthold cites from Osthoff, the case of a person, of forty-eight years of age, affected with hydro-cephalus, in which, instead of a chiasma, the two nerves, at the distance of half an inch from each other, were united by a small nerve, passing, like a bridge, from one to the other.

The case mentioned by Rudolphi, appears to disprove the opinion of the complete decussation of the optic nerves; yet, he admits, that, in cases of blindness of one eye, which has continued for a long time, the nerve of the opposite side, behind the chiasma, and the corresponding thalamus, become smaller, or wasted; although the fact, that the portion of each optic nerve, which is derived from the thalamus of the same side, constitutes, by far, the greater part of it, would lead us, he says, to expect the contrary.

The optic nerve, after piercing the sclerotic and

* Anat. Pathol. vol. iii. p. 399.

choroid coats, is distributed upon the retina, or, according to some anatomists, is expanded over the choroides in such a manner, as to form the interior tunic of the eye.

Besides receiving the optic, the eye is abundantly supplied with nerves, from other sources. Thus, the third pair of cerebral nerves is distributed to all the muscles of the eye, except the *trochlearis* and *abductor*. The fourth pair is wholly distributed to the superior oblique, or *trochlearis;* and the sixth pair, to the abductor. The ophthalmic branch of the fifth pair, also, enters the orbit, subdividing, into three secondary branches, the *lachrymal*, the *frontal*, and the *nasal*, which are distributed to the eye, and the neighboring parts. The office of these branches of the fifth pair, is supposed to be, to bestow common sensibility upon the eye, and its appendages. It appears, however, from Magendie's experiments, that the influence of the fifth pair is necessary to vision. The division of this pair of nerves, within the cranium, was found, not only to destroy the general sensibility of the eye, but almost wholly to abolish vision. It is remarkable, that the nerve of specific sensibility, the optic and its peripheral expansion, the retina, as well as the motory nerves of the eye, the third, fourth, and sixth pairs, appear to possess no general sensibility. The same is true of those parts of the brain, with which the optic nerves are immediately connected, viz. the thalami nervorum opticorum, and the superficial part of the tubercula quadrigemina. Twigs of the facial nerve also anastomose with twigs of the ophthalmic branch of the fifth pair, and are distributed to the orbicularis palpebrarum corrugator supercilii, and the occipito-frontalis.

The iris receives its nerves from the ciliary, which proceed from the ophthalmic, or lenticular ganglion. This is a small, reddish ganglion, situated on the external side of the optic nerve, imbedded in cellular tissue. It is formed by a twig of the third pair, and the nasal branch of the ophthalmic. The ciliary nerves, varying in number and disposition, proceed from this

ganglion, and passing along the optic nerve, to the sclerotic coat of the eye, penetrate this tunic, and run between it and the choroid coat, to the iris, on which they are distributed.

Blood-vessels of the eye.—The eye is supplied with blood, by the ophthalmic artery, which is a branch of the internal carotid. It enters the orbit at the foramen opticum, with the optic nerve, invested with a sheath, from the dura mater. In its course, it gives off several branches to different parts of the eye, and its appendages; among which, is a small vessel, called the central artery of the retina, which pierces the optic nerve, passing through its centre, to the internal surface of the retina, where it divides into a number of minute twigs. One of these penetrates into the vitreous humor, supplies the tunica hyaloidea, and proceeds onward to the capsule of the crystaline lens.

The ciliary arteries are very fine vessels, varying in number, from six to twelve. Some of them derive their origin immediately from the trunk of the ophthalmic artery; and others, from some of its branches. Those, which originate from the ophthalmic artery itself, are the most numerous. They divide into a great number of branches, forming a circle round the optic nerve, pierce the sclerotica, near this nerve, and are distributed upon the choroid coat, and the ciliary processes. One or two twigs, on each side, pass on between the sclerotica and choroides, to the ciliary zone, which they supply, and, afterwards, are distributed on the anterior surface of the iris, where they form beautiful circles, by the inosculation of their branches. Those of the ciliary arteries, which arise, not immediately from the trunk of the ophthalmic artery, but from some of its branches, are destined particularly to supply the iris. They also send delicate twigs to the conjunctiva, and the sclerotica, which last membrane they pierce, a small distance behind its union with the cornea. These are called the anterior ciliary arteries.

The blood, distributed to the eye by the ophthalmic artery and its branches, is returned by the ophthalmic

vein, which accompanies the artery in all its ramifications—passes out of the orbit, by the foramen lacerum anterius, and opens into the cavernous sinus.

Besides the essential parts of the eye above described, there are certain appendages to it, called, by Haller, *tutamina oculi*, designed to protect the organ from injury, and to preserve it in a proper condition to perform its functions. These are the eye-brows, the eye-lids, and the apparatus for secreting the tears.

The eye-brows are two hairy arches, crowning the superior part of the orbit, consisting of cellular tissue, a muscle, termed the *corrugator supercilii*, the common integuments, and short hairs, usually of the same color with that of the hair of the head, and directed, obliquely, outwards. The eye-brows give great expression to the countenance, and are also supposed to be useful, in screening the eye from too strong a light. The office of the corrugator supercilii, is, to knit the eye-brows.

The eye-lids are two movable, semi-transparent, crescent-shaped curtains, slightly convex outwardly. The inferior palpebra is composed of the common integuments, which are very thin, of delicate cellular tissue, and of the fibres of the *orbicularis palpebrarum;* the same parts, together with the fibres of the *levator palpebræ superioris;* of an oblong cartilage, called the *tarsus* of the ciliary glands, of eye-lashes, and, internally, a mucous membrane, called the *conjunctiva*, which is reflected over the ball of the eye. The tarsi are situated at the edge of the eye-lids, and serve to give them support, and keep them expanded.

Between the duplicature of the eye-lids, lie the ciliary, or meibomian glands, amounting to thirty or forty, in the upper eye-lid, and somewhat fewer, in the lower. They secrete an unctuous matter, which is discharged by the orifices of these glands, at the ciliary margin of the eye-lids. These orifices are called the ciliary ducts.

The borders of the eye-lids are elegantly fringed with rows of stiff hairs, called the *cilia*, or eye-lashes,

originating from the integuments, by slender roots. The lachrymal gland, is an oval-shaped, glandular body, situated at the upper and exterior part of the orbit, within the external angular process of the frontal bone. Seven or eight excretory ducts lead from this gland, and open on the inner side of the upper eye-lid, near the outer angle of the eye. The tears, secreted by the lachrymal gland, pass through these ducts, and are diffused over, and lubricate the eye. Near the inner angle of the eye, on the margin of each eye-lid, is a small orifice, called the *punctum lachrymale*. Each of these orifices forms the commencement of a small tube, termed the *lachrymal duct*, which passes towards the nose, and opens into the *lachrymal sac*, the commencement of the *nasal* duct, through which the tears are conveyed into the nostrils.

At the inner angle of the eye, between the eye-lids, is situated a small conglomerate gland, studded with short hairs. It is a congeries of small mucous follicles, similar in structure to the ciliary glands; and it secretes a thick unctuous fluid, analogous to the secretion of these glands.

The parts of the eye immediately concerned in vision, are the transparent coats and humors, which *refract* the rays of light in such a manner as to form on the retina images of the objects we behold; and the retina and optic nerve, which, by means of these images, convey the impressions of visible objects to the brain, where they give rise to sensation.

The refracting powers of the eye are the cornea, or the transparent coat, through which we look into the eye, and the three humors, the aqueous, the crystaline lens, and the vitreous.

The mode, in which images are formed at the bottom of the eye, on the retina, by the physical action of the transparent parts, will be understood from the laws of optics. Objects are seen by means of the light emitted by, or reflected from them. Light is projected from luminous bodies, in right-lined, diverging rays. From every point, a cone of these rays is emitted, the

apex of which touches the luminous point, and the base of which rests on the body, which receives the light. Every body, therefore, in the neighborhood of a luminous object, will receive cones of rays from every point of the latter, on the side directed to the former. If the receiving body be smaller than the luminous one, it is evident that the cones of light projected from the extreme parts of the latter, must converge together upon the former. So that a compound cone or pyramid of light will extend between the luminous and the receiving body, made up of the cones of rays projected from every point of the former, whose bases meet and are mingled together on the receiving object. This pyramid of light will be truncated, and the direction of it will be the reverse of that of the cones, of which it is composed. For, its obtuse apex will touch the body which receives the light, being composed of portions of the bases of the primitive cones; while its base, formed of the innumerable summits of these cones, will rest on the luminous body. In this manner all luminous objects, seen by the eye, project cones of light upon it from every visible point of their surfaces, and of these cones collectively, are composed pyramids of rays, of which the eye is the apex, and the luminous objects, the bases.

It has already been observed, that the eye is a dioptric instrument, the use of which is to refract the rays of light which enter it, in such a manner as to form images of visible objects, at the bottom of the eye on the retina. It is here necessary to advert to some other physical laws of light. When light is emitted by one luminous body, and falls upon another, it undergoes various modifications according to circumstances. 1. It may pass through the body on which it falls, either preserving, or *changing* its primitive direction, as the case may be, and frequently undergoing decomposition; in this case, the medium through which the light thus passes, is said to be diaphanous, or transparent, and the science, which teaches the laws of its transmission, is called *dioptrics*. 2. Or, none of it may enter the body on which it falls, but the whole

of it may be *reflected* from the surface of the latter; in which case the receiving body is white, and is said to be opake, and the branch of optics which teaches the laws of the *reflection of light*, is called *catoptrics*. 3. Or, the light may be wholly *absorbed* by the body on which it falls; which, in that case, is *black* and *opake*. 4. Or, in fine, the light in falling on the object may be decomposed, some of its constituent or calorific rays being absorbed by the body and combining with it; while the rest are reflected from its surface, and give the body its color. Several of these modifications, the rays of light which fall upon the eye, are made to undergo. Some of them which fall upon the transparent cornea, pass into the eye and traverse the humors, which are exquisitely transparent; some pursuing their original direction, others being more or less *deflected*, or bent out of it. Most of those which fall upon the white of the eye, are reflected back. Of those which enter the eye, a part fall upon the colored ring, called the iris, where they are decomposed, part of their constituent rays being absorbed, and the others reflected back from the iris, and giving this delicate membrane its expressive colors. Those rays which pass through the pupil, are lost in the depths of the eye, where they are employed in tracing images of objects on the retina, and the superfluous ones are absorbed by the black varnish of the choroid coat, and the uvea. It is only those rays, however, which traverse the humors of the eye, and at last fall upon the retina, which are subservient to vision. Most of these rays in their passage through the eye, undergo various modifications, which are essential to the functions of this sense; and an explanation of these is necessary to an understanding of the physical part of vision. When a ray of light is emitted by a luminous body, it undergoes no change in its primitive direction, so long as it continues to move in the same transparent medium, whether air or water, or glass, &c. So, if we suppose several different media forming parallel strata, and a ray of light to fall perpendicularly upon the exterior one, it would traverse all of

them without changing its direction. But, if we suppose a ray to pass *obliquely*, out of one medium into another of different density or nature, as out of air into water, or out of glass into air, this ray, in its transition from one to the other, will experience a sudden change in its direction, and become bent, or *refracted* out of its original course; and the new direction which it will assume, will, according to certain circumstances, be either *towards* or *from*, a line drawn perpendicularly to the surfaces of the two media, in contact with each other. In passing obliquely through several parallel strata of different densities, it would change its direction every time that it passed out of one into another, and exactly at the moment of its transition.

It appears therefore, that for a ray of light to be refracted, it is necessary that it pass out of one medium into another of a different density, or constitution; that its direction be oblique to the surface of the latter, and that this be transparent, so as to give passage to the ray through its substance.

The circumstances, which regulate the direction in which the ray is refracted, in relation to the perpendicular, are the curvature, or sphericity of the surface on which the incident ray falls; the density of the medium which it enters and traverses; and the degree of combustibility of this medium. So, whenever a ray of light passes through a series of transparent bodies, differing from one another in the curvature of their surfaces, their density and combustibility, it will experience, at every transition, a change more or less considerable in its direction.

When a ray passes obliquely into a different medium, which presents a *convex* surface, or has a *greater density*, or, is more *combustible* than that out of which it passes, its new direction will be *nearer* to the perpendicular to the surface of the medium. If it passes obliquely into a medium, which presents a *concave* surface, or is *less dense*, or *less combustible*, it will assume, after its refraction, a direction *further* from the perpendicular.

The cause of the refraction of light, is supposed to

be an attraction, exerted by the refracting medium upon the luminous rays. When these fall perpendicularly upon the surface of the former, the attraction is equal on the two sides, and no deviation takes place. But, if the line of incidence be oblique to the surface of the medium, the attraction will be unequal on the two sides, and will preponderate on the side towards the perpendicular, so that the rays will be attracted in this direction. A convex surface is favorable to refraction, by increasing the obliquity of the incident rays. Superior density operates in producing refraction, by exerting a superior affinity for the luminous rays. The presence of an inflammable principle in the refracting medium, appears also to increase the affinity of the latter, for the rays of light. This curious physical relation, led Newton to the most remarkable and fortunate conjecture, that both water, and the diamond which possesses great refractive powers, contain inflammable ingredients. The diamond, which is superior to almost all other substances, in refractive power, is now known to be pure crystalized carbon. Another substance, possessing a very high refractive power, is the *bisulphuret of carbon*, a transparent fluid, composed of two combustible ingredients, sulphur and carbon, and highly inflammable itself.

Now, a transparent, refracting substance may be made of such a shape, as to cause the diverging rays of light, which fall upon and pass through it, from any given point, to converge together so as at length to meet in another point, corresponding with that from which they were emitted; and as the surface of every visible object may be considered as composed of an infinite number of luminous points, the corresponding points or foci, into which the rays proceeding from them, are collected by such a refracting substance, will collectively form an exact image of the object. A convex glass lens, for example, will cause the rays of light, which enter it obliquely from any object before it, to converge to a focus; that is, it will bend them out of their original directions, towards a line

drawn perpendicular to its own surface. For all the perpendiculars to the surface of a convex lens, would meet at the centre of the sphere of which that lens is a segment. Hence the rays of light which enter the lens from any point in an object before it in being refracted towards a perpendicular, would be made to converge towards one another, and if prolonged sufficiently, would, at length, meet at a point or focus more or less distant from the centre of convexity of the lens. And all the points or foci thus formed by cones of rays proceeding from all the points of the luminous object would together form a perfect image of the object; each luminous point in the object, being represented by a corresponding point, or focus in the image. The greater the convexity, and the greater the density of the lens, the more will the light be refracted or bent out of its original direction, and the nearer will the focus or image be brought to the centre of convexity of the lens. From these principles it will appear that the rays of light which enter the eye from visible objects, and pass through the pupil, will undergo successive refractions, until at last the rays proceeding from any given point of the object we are looking at, will, after their entrance into the eye, be made to converge so as at length to be brought to a focus in the bottom of the eye; and in this manner a perfect image of the object will be formed in the eye. All the humors of the eye have a much greater density than the atmosphere; and the eye when light passes into it, presents on its anterior part the form of a convex lens. Of course, when a beam of light strikes on the cornea, the rays which fall perpendicularly upon it, will enter the eye and pass on without changing their direction; but those which strike it obliquely, will, after entering the eye, be refracted towards the axis of the organ, in consequence of the convexity of the cornea, and the density of the aqueous humor. After taking their new direction towards the axis, or centre of the eye, some of the rays will fall upon the iris, part of them be absorbed by this opaque body, and part be reflected back from it out

of the eye, and enable us to see the color of this delicate membrane. But the rays which pass through the pupil, will almost immediately fall upon the crystaline lens, a body which has a much greater density than the aqueous humor, and is convex on both surfaces; and, consequently, the rays of light in passing into it from the aqueous humor, will suffer a greater degree of refraction, and be made still more to converge towards the axis of the eye; and towards each other. The crystaline lens is the principal refracting power of the eye, when it is moved from the eye, or from the axis of vision, in operations upon the organ, it becomes necessary to supply its place by the use of convex glasses. By the convergency which the rays of light experience in passing through the crystaline lens, the intensity of light which falls upon the retina must be increased, because, by means of this convergency, the rays will be collected into a narrower field. Not all the rays, however, which fall upon the crystaline lens, are transmitted through it; part of them are reflected back through the aqueous humor, out of the eye again, and contribute to give the organ its brilliancy and sparkling appearance. Those rays, which traverse the lens, are received by the vitreous humor, and conveyed to the retina, where they unite, in points corresponding with those from which they were radiated in the luminous body, and forming an image, which is an exact, though inverted representation of the object. This image is inverted, because the rays of light cross each other in passing through the crystaline lens; those rays, which proceed from the upper part of the object, uniting to form the lower part of the image, and vice versâ; so that the image will represent the object reversed, or upside down.

That this is actually the fact, is demonstrated by experiment. If the eye of an animal, after removing the posterior part of the sclerotica, be placed in an aperture, in the window-shutter of a darkened room, there will be distinctly seen, painted on the retina, the images of such objects as transmit rays of light through the pupil of the eye.

The vitreous humor, which receives the rays from the crystaline lens, has a less degree of density than the latter; and, according to the principles before mentioned, which regulate the refraction of light, the rays, in passing out of the crystaline into the vitreous humor, will be refracted *from*, instead of *towards* a perpendicular to the surface; and it will appear, from considering the direction of this perpendicular, that the rays, in being refracted *from* it, will be made to approach *nearer* to the axis of the eye, and will, consequently, be rendered still more convergent; so that the vitreous humor, though possessing less refractive power than the lens, yet, by its presenting a *concave*, instead of a *convex* surface, is made to coöperate with the aqueous humor and the crystaline lens, in conveying the rays of light, which pass through the eye, and bringing them to a focus, on the retina.

On the whole, the organ of vision consists of a complex apparatus, of three refracting powers, by which the rays of light, which enter the eye from visible objects, are bent out of their original direction, and made to converge to certain points, or foci, on the retina, corresponding exactly with the points of the objects from which they were radiated, and forming miniature paintings or images of them, on the bottom of the eye. If the rays of light were not thus refracted, but if, after entering the eye, they continued to pass on, each in its primitive direction, all the rays, proceeding from every point of the visible objects, would be diffused promiscuously, and blended together, over the whole field of vision, so as not to form images on the retina, but only a confused expanse of color. This may be illustrated, in a very simple manner. The rays of light, from the numerous objects without, which enter the window of an apartment, do not form images of these objects on the opposite walls of the apartment, because they are not refracted, and collected together into foci, corresponding with the points from which they were emitted, but continue to pass on, each in the direction in which it was projected, after they have entered the

room. All the cones of rays, which radiate from every point of the objects, visible from the apartment, enter it through the window, and pass on, preserving the same direction, till they strike upon the wall, where they form a mingled mass of light. Now, if the room be darkened, and a small aperture only be left in a shutter, in which is placed a convex lens, the rays of light, which enter the room, must first be refracted, in passing through the lens; and they will be made to converge to a focus, at a greater or less distance from the lens, according to its convexity, or refractive power, and will arrange themselves in points, corresponding, in color and relative situation, with those of the objects from which they were emitted, so as to form exact, but inverted pictures of them. In a word, the rays of light, projected from every point of a visible object, which enter the eye, pass through it, and fall upon the retina, form two cones, having a common base. One cone is formed by the rays, as they *diverge* from the luminous point, until they fall upon the cornea, which forms the base of the cone; the second, is formed by the same rays, as they *converge* from this base, in their passage through the eye, until they unite, at a focus, or point, on the retina, which constitutes the apex of the cone. As the rays of light, however, undergo, at least, three refractions, after entering the eye, and change their direction, and become more convergent every time they pass from one humor to another, it is evident, that the second, or ocular cone, is a figure, composed of parts, *frustra* of three cones, differing from each other in their acuteness, or the inclination of their sides to their bases. The whole body of rays, which enter the eye from the object, made up of the primitive cones, form two pyramids of light, joined together by their summits. The base of the objective pyramid rests on the object which projects the light, and its apex is at the centre of the crystaline lens, where the rays from the object decussate; the apex of the ocular pyramid is also in the centre of the lens, and its base rests upon the retina. On the whole, the mechanism of vision

seems to be subservient to the purpose of forming images of visible objects, at the bottom of the eye; and these images, in some way or other, we know not how, or why, are necessary to vision. The eye, in fact, is a true *camera obscura*. The images, formed on the retina, are extremely minute; a fact which depends on a well-known optical principle, viz. that "the size of an image, formed behind a lens, is always proportioned to its distance from the lens, and the image is as much larger or smaller than the object, as it is farther from, or nearer to, the lens than the object." The little luminous circle, which the focus of a burning-glass presents, is, properly speaking, an image of the sun; and this image is as much smaller than this vast luminary himself, as it is nearer to the lens by which it is formed. On the same principle, not only the vastest object in nature may be painted on a minute spot in the retina of the eye, but a boundless extent of ocean, earth, and sky, with innumerable objects, of every variety of shape, color, and dimension, may be crowded together, yet without the least confusion, and every object preserving its exact proportions, its color, shape, and relative size, &c. on a little concave, not larger than the cup of an acorn.

In order to be visible, an object must subtend an angle of more than thirty-four seconds.

The offices of the different parts of the eye may be determined, in many instances, not only from their structure and situation, but by removing them, separately, from the eye of an animal, and then observing how the images on the retina are affected by their absence. Thus, it is found, that, if the aqueous humor be evacuated through a small opening in the cornea, the images, formed on the retina, appear much larger, and less distinct, and less luminous, than before the removal of the humor; all of which circumstances prove, that the rays of light, emanating from the luminous points in the visible objects, are not, as in perfect vision, sufficiently refracted to be brought to corresponding points, or foci, when they reach the retina; but, that the summits of the ocular cones fall

behind, or beyond this membrane. The more, within a certain limit, the rays converge towards each other, the smaller, more distinct, and more luminous, will be the image formed on the retina, and vice versâ.

The crystaline lens, it has been remarked, is the greatest refracting power of the eye, as is evident, from its superior density, and from the convexity of both its surfaces. Its office, therefore, must be to increase the convergency of the rays of light, after passing through the aqueous humor, and to diminish the size, and to increase the distinctness and brilliancy of the images. Accordingly we find, that, when the crystaline lens is removed from the eye, the image of an object, formed on the retina, is considerably larger than before, but very indistinct, and feebly illuminated. The light is weak, because the same quantity is diffused over a much larger surface. The size of the image is said to be increased fourfold, by the absence of the crystaline lens. When it is removed, in the operation for cataract, it becomes necessary to supply its place by very convex glasses. In fishes, the crystaline lens is nearly spherical, the iris lying in contact with the cornea, and, of course, leaving no space for the anterior chamber of the eye. This great convexity of the lens in fishes, is necessary to increase the refractive power of the eye under water—because the difference of density between the two media, water and the humors of the eye, is vastly less than that between these humors and the atmosphere; and, consequently, the refraction of light will be proportionably less. For the same reason, convex glasses are necessary to enable a man to see well under water.

The evacuation of the vitreous humor from the eye, leads to similar results, proving that this, also, is one of the refracting powers of the organ. If both the aqueous humor and the lens are removed from the eye, the rays of light, which enter it, will not be sufficiently refracted to form an image on the retina. Sometimes, the focus of the refracted rays, instead of falling exactly on the retina, either falls short of, or is produced beyond it. The former defect gives rise to *myopia*, or

short-sightedness, the latter to *presbyopia* or long-sightedness. *Short-sightedness*, which generally occurs in young persons, is usually ascribed to too great convexity of the crystaline lens, or prominence of the cornea, producing too much refraction of the light; in consequence of which, the rays are brought to a focus before they reach the retina; but it has also been supposed to arise from an increase of density in the central parts of the crystaline lens.

Long-sightedness usually shows itself about the age of forty, and arises from a mechanical change in the state of the crystaline lens, by which its density and refractive powers are altered. The variation of density is said to take place most frequently at a particular point in the margin of the lens, and to require some time to complete its circle. At its commencement, vision is considerably injured; but when the change has become symmetrical round the margin of the lens, a convex lens enables the eye to see as distinctly as before.

The office of the iris is, to regulate the quantity of light admitted into the eye. Whenever the organ is exposed to an intense light, the pupil contracts almost to a point, so as to permit only a very small pencil of the contracted rays to fall upon the retina. In a faint light, on the contrary, the pupil dilates so as to open a free passage for the admission of light.

The motions of the iris have been differently accounted for. Some physiologists contend, that its structure is muscular, and that it contracts like other muscular parts. According to Mr. Bauer's observations, there are two sets of muscular fibres in the iris, one radiated, the contraction of which enlarges the pupil; the other, circular, and forming a constrictor, or sphincter of the pupil. Home, Bell, Berzelius and Magendie, also, maintain this opinion. Other physiologists deny the muscularity of the iris, and contend that it belongs to the erectile tissues, and is formed by an interlacement of the ciliary vessels and nerves, connected by cellular tissue; that it dilates or contracts by admitting a more or less considerable quan-

tity of blood, according to the degree of excitation produced by light; the size of the pupil and the quantity of light admitted through it, being determined by the degree of this dilatation, or contraction. A majority of physiologists appear to have adopted the latter opinion. Blumenbach says, that the iris does not contain a vestige of muscular fibre. Rudolphi says, that he has never seen any thing that deserved the name of muscular fibres, either in the iris of birds, in which Treviranus asserted their existence, or in that of any other animal.* The motions of the iris are determined, not by the direct impression of light upon this membrane itself, but, by its action on the retina. In an experiment of Fontana, a small pencil of rays was thrown upon the iris, which excited no motion in the membrane; but, when it was afterwards directed upon the retina, the iris immediately contracted. Pelletier mentions a case of cataract in the left eye, in which the opacity of the lens was so perfect, that the eye could perceive no difference between night and day. A transition from the most perfect darkness to the brightest light, occasioned no contraction of the pupil, though the light fell directly upon the iris. But, upon opening and shutting the sound eye alternately, the pupils of both eyes contracted and dilated successively. Another fact, which appears to be inconsistent with the opinion of the muscular nature of the iris, is, that it seems to be insensible to irritation applied directly to it. Pricking it with a needle occasions no motion in it; yet the application

* Rudolphi admits, however, that the iris, though not muscular, contracts like the sphincter muscles, whose exterior and inner parts act like antagonists. When the outer circle of the iris contracts, the pupil dilates; when the inner, the pupil contracts. The larger or outer circle predominates in substance over the inner, and, of course, naturally overpowers the latter in the energy of its action. Hence after death, or apoplexy, or paralysis, the pupil is dilated. But, during life and health, the smaller or inner circle gets the ascendency, in consequence of irritations internal and external, so that, for example, in looking at a near object, or by a strong light, the smaller circle overcomes the larger, and the pupil contracts. Narcotics, employed either internally or externally, either excite the outer, or paralyze the inner circle, and thus produce dilatation of the pupil.

of galvanism is said to cause it to contract. In some species of birds, its contractions appear to be under the influence of the will. Thus, parrots are said to have a voluntary power of dilating and contracting the pupil, in viewing the same object, and with the same light.

The section of the optic nerves and the ablation of the tubercula quadrigemina produce permanent dilatation of the pupils. The section of the fifth pair of nerves, also occasions immobility of the iris, with this peculiarity, however, that the pupil is contracted. Mayo, however, denies that dividing the fifth pair has any influence upon the iris. It merely produces insensibility of the eye-ball. But he asserts, that the section of the third pair, paralyzes the iris; and it is worthy of remark, that, in the eagle, according to Desmoulins, the iris derives all its nerves from the third pair.

That the division of the third pair, as well as that of the fifth, should occasion immobility of the pupil, will not seem surprising, when we consider that the lenticular ganglion, from which the ciliary nerves proceed, is formed by a twig from each of these nerves.

It is remarkable that, in some cases of *gutta serena*, the pupil contracts and dilates freely. The pupil was found dilated by Tiedemann, in a marmot during its torpidity. According to Rudolphi, it is generally in this state after death; though he says he had often found it contracted.

Magendie asserts, that the effort required to see minute objects distinctly, occasions a contraction of the pupil. The same physiologist found that, if the pupil was enlarged by cutting out a circular piece of the iris, the image formed on the retina became larger.

One important office of the iris is to serve, like the diaphragm of a telescope, to correct the spherical aberration of light. When light is refracted by a lens of uniform density, and of a spherical surface, the exterior rays, or those farthest from the axis of the lens, are too much refracted to meet in a principal

focus; but they meet and cross each other at a point nearer to the lens. A lens with a spherical surface, therefore, having the same degree of curvature every where, cannot refract all the rays to the same focus. To effect this purpose, it must be flatter towards the edges, so as to diminish the refraction of the exterior rays, or its figure must be that of an ellipse or hyperbola. The same effect may be obtained, however, by excluding the exterior rays, by means of a diaphragm, the aperture of which will permit only the central rays, or those near the axis of the lens, to fall upon it. The iris placed a little in front of the crystaline lens, performs the functions of a diaphragm, preventing the rays of light from falling upon the exterior parts of the lens, and admitting only those rays, which the lens can bring to a focus. The crystaline lens is supposed to contribute to the correction of the spherical aberration. It is composed of concentric laminæ, gradually increasing in density towards the centre. Of course, the exterior or cortical layers, from their inferior compactness and density, will exert less refractive power, than if the lens were of uniform density throughout, and the rays of light, which fall upon the lens furthest from its axis, instead of being refracted to a point between the principal focus and the lens, will be prolonged, till they meet at the former on the retina.

The use of the choroid coat, which is covered on both surfaces with a black varnish, is to absorb those rays of light, which have passed through the retina; as otherwise some of them would be reflected back through the retina, and produce confusion of the images formed on that membrane. In the albinos the black matter is wanting, in consequence of which the eyes are extremely tender and impatient of the light, and in the day-time, vision is indistinct, while in the night, or by a feeble light, it is not impaired. Magendie remarks, that, in persons affected with a varicose state of the vessels of this membrane, the dilated vessels lose their coating of black matter, and whenever the image of an object falls on that part of the retina

which corresponds to these vessels, the object appears to be spotted red, owing to the circumstance, that the light, which passes through the retina, in vision, is not absorbed by black pigment at these points.

The office of the retina is, to receive the impressions of visible objects, and, by means of the optic nerves, to transmit them to the brain. It appears, from experiment, that this membrane, as well as the optic nerve, possesses but little *general* sensibility. Magendie found, that the retina might be irritated, and even torn, by a couching needle, without exciting any appearances of suffering in the animal. The general sensibility of the eye, as before observed, is derived from the fifth pair. It appears, from the experiments of Magendie, that the coöperation of the fifth pair, which is the nerve of common sensibility, is necessary to enable the retina to exercise its specific functions, of receiving visual impressions. It would appear, indeed, from one extraordinary case, mentioned by this distinguished physiologist, that the function of the optic nerve, under some circumstances, may be assumed by some other, probably the fifth. The case alluded to, was that of a man, who enjoyed the use of his eyes, though a cyst, situated in the course of the optic nerves, had entirely destroyed these nerves, and separated the part anterior to the decussation, from the posterior part.

To the due action of the retina, it is necessary that the light, which falls upon it, should be neither very feeble, nor very intense. A very feeble light makes no impression upon this nervous tunic; a very intense one, on the contrary, overpowers its sensibility, and produces the effect called *dazzling*. The sensibility of the membrane appears to be exhausted by the sudden and violent stimulus of a strong light, so that the eye, for some moments, remains insensible to its presence.

It has been ascertained, by experiment, that the spot in the retina, where the optic nerve enters the eye, is insensible to light. The experiment consists, in placing two colored wafers upon a sheet of white

paper, about three inches apart, and looking at the left-hand wafer, with the right eye, at the distance of about a foot. When this is done, and the left eye closed, the right-hand wafer will not be visible. The same effect will be produced, if we close the right eye and look with the left, at the right-hand wafer; and, upon examination, it is found that the spot, on which the rays from the *invisible* wafer fall, corresponds with the base of the optic nerve, or the place where this nerve enters the eye.

It has been generally supposed, that the eye possesses the faculty of accommodating its refractive power to the different distances of the objects it beholds. The degree of refraction, which the light from a distant object undergoes, in order to form a distinct image on the retina, would not be sufficient to produce the necessary convergency in the rays, proceeding from an object nearer the eye. The focal point of these rays would not be on the retina itself, but at a greater or less distance behind it. This is evident, because the rays, proceeding from remote objects, as they diverge less, will require a less degree of refraction in order to bring them to a focus, than such as are projected from objects nearer the eye. Hence it appears, that a different refractive power must be exerted by the eye, in forming distinct images of near and distant objects. Admitting the existence of such a power in the eye, it is not easy to determine on what mechanism it depends. By some physiologists it has been referred to a supposed action of the ciliary processes, of changing the distance of the crystaline lens from the retina. Others suppose, that the action of the recti muscles of the eye, the tendons of which extend over a part of its surface, effect a change in the form of the eye-ball, by compressing it in such a manner as to cause a certain degree of protrusion of the cornea, and thus to increase the convexity of this tunic, and the distance between it and the retina.

Dr. Young, and some others, refer the power of adjustment to a change in the figure of the crystaline lens itself; an opinion, founded on the supposed struc-

ture of the lens, in which Young conceived that he had detected a fibrous appearance.

The mobility of the pupil is another cause, which has been called in, to account for this effect. The pupil contracts when we look at objects near the eye, so as to admit those rays only which are near the axis of the eye, and which require less refraction than those which are further from it; and, on the other hand, it dilates when we look at remoter objects, so as to admit the exterior rays, which are most distant from the axis, and which require, for their convergency, a greater degree of refraction. So that the same power of refraction may be made to serve both for near and for distant objects, merely by excluding, in the one case, and admitting, in the other, those rays which require the greatest refraction. This contraction of the pupil, when we view objects near the eye, may also produce the effect of bringing forward the crystaline lens; for, as the base of the iris is connected with the ciliary processes, which suspend the lens, the latter will be brought forward, or removed further from the retina, by the expansion of the iris, towards the centre of the pupil.

A cause of the indistinctness of images, formed by the rays of light which have been refracted by lenses, results from the different degrees of refrangibility of the elementary rays of white light. The consequence of this difference of refrangibility is, that, whenever solar light is refracted, it is decomposed, or separated, into its constituent rays; for, those rays which are most refrangible, will necessarily separate from those which are least so; and the refracted beams of light, instead of converging to a precise focus, and forming an exact image of the object, will exhibit an indistinct image, fringed with the colors of the solar spectrum. This effect is termed the *aberration of refrangibility*, or the *chromatic dispersion* of light; and it is obviated in the construction of telescopes, by using compound object-glasses, made of different kinds of glass, and which are termed *achromatic*, i. e. without color.

Many philosophers are of opinion, that the eye is

an achromatic instrument, with its different refractive and dispersive powers so adjusted to each other, as to destroy this aberration of refrangibility. Euler was of opinion, that the achromatism of the eye, was owing to the different refractive powers of its humors.

Others have referred it to the structure of the crystaline lens, the layers of which, being of different densities and dispersive powers, might correct each other, like the different pieces of a compound object-glass.

It has been a question, why we do not behold objects in the same position, in which their images are formed on the retina. We see objects in their natural positions; while the images of them, painted in the eye, are inverted. Various explanations of this fact have been proposed, but, perhaps, none of them is perfectly satisfactory. The fact appears to be, that the mind judges of the position of objects, by the direction in which the light proceeds from them, towards the eye. According to Brewster, when a ray of light falls upon any point of the retina, in any direction, however oblique to the surface, the object will be seen in the direction of a line, perpendicular to the retina, at the point of incidence; and, as the retina is a portion of a sphere, all these perpendiculars must pass through one point, which may be called the *centre of visible direction;* because, every point of an external object will be seen in the direction of a line, joining that centre and the given point. The line of visible direction is a line, drawn from the point at which the ray strikes the retina, through the centre of the crystaline lens. Treviranus accounts for it, by supposing that the filaments, from the upper part of the optic nerves, are distributed to the lower part of the retina, and those from the left side of the nerve, pass over to the right side of this membrane. This decussation, he supposes not to take place at the commissure, but at the place where the nerves pierce the choroid coat.

According to Sir C. Bell, we judge of the position of objects, by the feelings which accompany the

motion of the muscles of the eye. "When an object is seen," he says, "we enjoy two senses; there is an impression upon the retina; but we receive, also, the idea of position, or relation, which it is not the office of the retina to give. It is by the consciousness of the degree of effort, put upon the voluntary muscles, that we know the relative position of an object to ourselves."

According to others, we see every object, even our own bodies, in an inverted position; and hence, their relative position is preserved, in vision, exactly as if they were viewed erect. The part nearest the earth, we always consider as the lower part, and that farthest from it, as the upper part of an object. Hence, whatever part of the retina the image of the earth falls upon, that part of the image of the object, which lies next to it, will always suggest to us the idea of the *lower* part of the object, and vice versâ. If we suppose the position of every object to be reversed, and among them the beholder himself, they would appear erect, exactly as before. This is the case with those, who live on the part of the earth's surface precisely opposite to ourselves. Here, the position of every thing is exactly the reverse of our own, and of the objects which exist on this side of the earth's surface. Yet, the inhabitants of the opposite hemisphere do not see the objects around them, as they appear to our imaginations, upside down, but, as they are in fact, precisely as erect as the objects about us appear to ourselves. Leidenfrost, according to Rudolphi, witnessed a case of congenital blindness, in which, the patient, a young man, recovered his sight after an inflammation of the eyes, and saw every object, trees, men, &c. in an inverted position. After a time, he learned to judge of their position, like other men. This would tend to confirm Buffon's views, that, originally, we do see objects inverted; but, that the error is corrected by the sense of touch. Other cases of blindness from birth, however, in which sight has been restored, have exhibited a different result.

Another question which has been raised, is, why

we see objects single with two eyes. This is supposed to be owing to a certain correspondence and harmony of action, between the centres and other points, similarly situated, of the two retinæ; so that the two images, formed on corresponding parts of the two retinæ, coalesce into one; and those which are formed on points which do not harmonize in action, suggest two visible appearances, although they proceed from one object only. By voluntarily changing the axis of one of the eyes, so that the images shall not fall upon harmonizing parts of the two retinæ, we can, at any time, produce the phenomena of double vision. Blumenbach ascribes single vision with two eyes, to the power of habit. Infants, he remarks, at first see double; and the double vision, which sometimes remains after certain diseases of the eyes, is gradually removed by practice and experience.

It sometimes happens, that double vision affects one eye only. This may happen from the cornea becoming *facetted*, in consequence of ulceration. Beer, according to Rudolphi, relates, that he had seen some examples of the kind, in which the patient, with the affected eye, beheld objects double, triple, or even quadruple. So, a double pupil has been known to cause double vision with one eye; as, in a case related by Reghellini,* in which, in a person blind of both eyes, the cataract of one eye was couched, and an artificial pupil was formed at the inner margin of the iris. The person recovered his sight, and the eye operated upon received the rays of light, both by the natural and by the artificial pupil; in consequence of which, he was affected with double vision of that eye. If the natural pupil was covered, the patient saw quite as well with the artificial pupil, as he could with the other. "A small object sometimes appears double with one eye, when the crystaline lens has ceased to be homogeneous, from age or disease."

The eyes of many insects are polyhedrous, with

* Rudolphi.

numerous facettes. "Dr. Hooke computed, in the two eyes of a dragon-fly, fourteen thousand facettes, and Lewenhoeck counted twelve thousand, five hundred and forty-four, in another species of this insect. Puget adapted the eye of a flea in such a manner, as to see objects through it by means of a microscope. A soldier, viewed through it, appeared like an army of pigmies; and the flame of a candle seemed like the illumination of thousands of lamps. In insects, a filament, from the optic nerve, goes to each facette of the cornea. Undoubtedly vision is single in insects, with these very compound eyes.

The eye, like the other organs of animal life, is subject to the law of alternate action and repose. It can continue in action only a limited time; after which, it requires a period of repose, before it can resume the exercise of its functions. This law of animal life, in its application to the eye, gives rise to some curious phenomena. If a small space of the retina be exposed to a strong light for a certain time, its sensibility to the stimulus of light is at length exhausted. If, for example, we look, for a few moments, at a white spot, on a dark ground, the point of the retina, on which the rays from the white spot fall, will, at length, become almost insensible to the presence of light; so that, if the eye be afterwards directed to a white surface, it will perceive a dark spot in it. Whereas, the other parts of the retina, which have not been stimulated, will become *more* sensible to the stimulus of light, so that the dark spot will appear to be surrounded by a dazzling light.

But, it appears further, if we look steadily, for a few minutes, at a small circle of *red*, as, for example, a wafer placed upon a white ground, we shall, in a few moments, perceive a light *green* border playing round the red circle; and, if we then remove the eye from the wafer, to direct it to a white surface, we shall see a circle, of a pale *green* color, exquisitely delicate, of the same size as the wafer. This green, is called the *accidental* color of the red. By similar

experiments with other colors, we learn that *red* is the accidental color of *blue; blue*, of *orange*, &c.

It appears from observation, that the accidental color of any primitive one, is that color which, in the prismatic spectrum, is distant from the primitive, half the length of the spectrum. It appears, also, that a primitive, and its accidental color, are complementary of each other; that is, that each of them is what the other wants to make it, white light; or, in other words, that the primitive and accidental color, mixed together, will form white light. Now, the production of accidental colors depends, partly on the physical constitution of white light, and partly on a physiological law, respecting the eye. It has been remarked already, that the retina, after being exposed a certain time to the stimulus of a strong light, has its sensibility to light temporarily diminished. And it appears further, that if the eye be exposed, for a short time, to the rays from a particular color, its sensibility to that color is diminished, and it ceases to receive any sensible impression from it. When the eye, therefore, after looking, for some time, upon a red wafer, is directed to a white surface as to a sheet of white paper, the part of the retina which had been previously stimulated by the red color, is no longer excited by the red rays existing in the white light, and, consequently, will not see a white color, but instead of it, that color which results from a union of all the colors which enter into the composition of white light, *with the exception of the red.* The white light is decomposed by the physiological action of the retina, and one of its component parts, viz. the red rays, is left out; and the result is that color, which is formed by a combination of all the other rays.

When the retina is highly excited by the action of colored light, the accidental color will be perceived, though much more faintly, even when the eye is shut. This is owing to the light, which is transmitted through the semi-diaphanous eye-lids.

CHAPTER XXIV.

Hearing.

The organ of hearing consists of a very curious and complicated apparatus. It is divided into an external, a middle, and an internal part, besides the auditory nerve, which is the immediate instrument and seat of hearing.

The external ear consists of an irregular, cartilaginous body, to which the term, ear, is popularly applied, and of a canal, which extends from the external ear, inwardly, and is bounded by a tense membrane, called the *membrana tympani.*

The external ear, or pavilion, is composed of a number of elastic fibro-cartilages, moved by a set of muscles proper to it, and covered by a fine skin, attached to the lateral part of the head on each side, below the temple, in front of the mastoid apophysis, and behind the cheek. Its external face presents a very irregular surface, varied by several eminences and depressions, which have received separate names.

The canal, which is called the *meatus auditorius*, or the auricular canal, extends from the bottom of the pavilion to the cavity of the tympanum, from which it is separated by the membrane of the same name. Its length is about ten or twelve lines. Its direction is obliquely forwards and inwards, and its course a little curved, so as to present a convexity upwards. The skin which covers it, presents a great number of minute orifices, or pores, which are mouths of the excretory canals of the ceruminous glands of the ear, which secrete the yellow bitter matter, called the cerumen of the ear.

The middle ear, or cavity of the tympanum, is an irregular, hemispherical cavity, hollowed out in the petrous part of the temporal bone, and separated from

the external ear, by the membrane of the tympanum. This cavity has six openings, a chain of four small bones, and several muscles and nerves. The cavities are, 1. outwardly, the internal orifice of the meatus auditorius, closed by the membrane of the tympanum. This is a thin, transparent, fibrous membrane, of an oval shape, and a little larger than the opening it is designed to close; so that it is capable of alternate motions of tension and relaxation. It is generally convex towards the cavity of the tympanum. According to Home, its fibres, in some large animals, as the elephant, are of a muscular nature;—2. a small orifice, the mouth of a short canal, which communicates with numerous cells, in the mastoid apophysis;—3. inwardly, and nearly opposite to the membrana tympani, is a third orifice, called the *fenestra ovalis*, forming a communication between the middle and the internal ear. It is closed by a fibrous membrane, to which is attached the base of the stapes, one of the small bones of the ear;—4. a round opening, called the *fenestra rotunda*, by which the middle ear communicates with the external scala of the cochlea, closed, like the former, by a membranous expansion;—5. at the anterior and inferior part, a small orifice, which is the mouth of a tunnel-shaped canal, about two inches in length, which opens in the posterior part of the nasal fossæ, behind the velum of the palate. This is called the Eustachian tube;—6. a sixth orifice, is a small fissure, called the glenoidal, through which passes the tendon of the anterior muscle of the malleus, and one of the filaments of the cranial branch of the fifth nerve, under the name of the *chorda tympani*. A chain of small bones, four in number, occupy the cavity of the tympanum, extending from the membrane of the tympanum, to that which closes the fenestra ovalis. The name of these bones, beginning with that which is attached to the membrana tympani, are the *malleus*, the *incus*, the *os orbiculare*, and the *stapes*. These ossicles are articulated together in the order above mentioned, and are moved by three small muscles, viz. the anterior, and the internal muscles of the malleus,

and the muscle of the stapes. By the action of these muscles, the chain of bones, and the membranes to which they are attached, may receive a greater or less degree of tension. A branch of the facial nerve penetrates into the middle ear, and bestows motility upon these muscles. The middle ear also receives filaments from the spheno-palatine ganglion. On the inner side of the membrana tympani, is distributed the chorda tympani, a twig of the facial nerve. The cavity of the tympanum is lined with a mucous membrane, which is prolonged into the Eustachian tube.

The internal ear is composed of several irregular cavities, excavated in the petrous part of the temporal bone. These cavities communicate with one another, and are divided into three parts, viz. the *vestibule*, the *semi-circular canals*, and the *cochlea;* and are, collectively, termed the *labyrinth*.

The vestibule is an irregular cavity, situated on the inside of the tympanum, exterior to the internal auditory canal, in front of the semi-circular canals, and behind the cochlea. As its name imports, it serves as a kind of antechamber to the semi-circular canals and the cochlea. In the vestibule, are found several foramina, viz. the internal orifice of the fenestra ovalis, covered by its proper membrane, and the base of the stapes. On the posterior side, five apertures, by which the three semi-circular canals open into the vestibule; on its anterior side, a large aperture, by which the cochlea communicates with the vestibule; at its inner surface, are numerous small holes, which give passage to blood-vessels, and to filaments of the acustic nerve, and which communicate with the meatus auditorius internus. Besides these, there is a small foramen, near the common orifice of the two vertical semicircular canals, which is the mouth of a very narrow duct, which opens about half an inch behind the meatus auditorius internus, into a small cavity, between the dura mater and the bone. This is called the *aqueduct of the vestibule*.

The three semi-circular canals are situated posterior to the vestibule, each forming nearly three-fourths

of a circle. They are excavated in the petrous part of the temporal bone, and they open by both their extremities, into the vestibule, by five orifices. Their direction is different, two of them being vertical, and the third, horizontal. Their walls consist of a compact plate of bone, lined with a periosteum, within which is contained a watery fluid, and a delicate pulpy membrane, on which is distributed part of the auditory nerve.

The third part of the internal ear, is the cochlea. This is a spiral canal, forming two turns and a half, and having some resemblance to a snail's shell. This canal is hollowed out of the anterior part of the petrous portion of the temporal bone, before and within the vestibule, and is divided into two parts, by a delicate, semi-osseous, spiral partition, which winds round a central conical pillar, termed the *modiolus*. The two canals, which are thus formed, are called *the scalæ* of the cochlea. The modiolus itself is hollow. One of the scalæ of the cochlea opens into the cavity of the tympanum, by the fenestra rotunda; the other, into the vestibule. They communicate together at the summit, by a small aperture.

The base of the modiolus is perforated with several minute foramina, through which the filaments of the auditory nerve, penetrate into the cochlea.

The auditory nerve, the eighth cerebral nerve, arises from the medulla oblongata, passes obliquely outwards, forwards, and upwards, and enters the meatus auditorius internus, the orifice of which is situated at the posterior surface of the *pars petrosa*. The base of it is cribriform, and corresponds to the base of the cochlea, and the inner surface of the vestibule. Here, the auditory nerve, dividing into minute threads, enters the labyrinth. The anterior fasciculus of these filaments is distributed to the cochlea; the posterior, upon the vestibule and the semi-circular canals.

All the cavities of the labyrinth are filled with a watery fluid, termed the *liquor of Cotunnius*, secreted by the membrane which lines them. This fluid is

supposed to be necessary to hearing, since deafness sometimes results from the absence of it.

The human ear, it will appear then, consists of a large, irregular, cartilaginous substance, commonly called the ear, a blind canal passing from this towards the internal ear, closed by a tense elastic membrane; beyond this membrane, a cavity filled with air, and communicating with the atmosphere by means of a canal, which opens into the superior part of the pharynx; a chain of small bones contained in this cavity, and connected, by one extremity with the membrane above mentioned, and by the other with the internal ear, the immediate seat of the sense of hearing, which is composed of various cavities and canals, excavated in a part of the temporal bone, lined with a delicate membrane, filled with a limpid fluid, and having distributed over them the minute branches of the auditory nerve.

Reduced to its greatest simplicity, the organ of hearing consists merely of a sac, inclosed in a hard cartilaginous or bony case, with nerves distributed over it, and filled with a watery fluid; so that vibrations affecting the hard elastic walls, may be communicated to the contained fluid, and the nerves, distributed over the sac. Such is the internal ear, in some of the lower orders of animals. As the organ becomes more complicated, we find added to this simple sac, some circular canals filled with water, communicating with that of the primitive sac, or the vestibule. Over the membrane lining these canals, nerves derived from the auditory, are distributed; and consequently a larger nervous surface is exposed to the vibrations of sound. In reptiles and fishes, there are small sacs in the labyrinth, containing little stones, or chalky bodies, which perhaps are the first rudiments of a cochlea. In birds, the cochlea is more developed, though still imperfect. To these more essential parts are successively added, as the organ is more fully developed, the middle ear, the chain of small bones, the cartilage of the ear, the more perfect development of the cochlea, &c.

Sound is excited by the vibrations of elastic bodies, which cause corresponding undulations in the air, and are conveyed by it to the organ of hearing. The particles of sounding bodies, when put in motion by percussion, vibrate backwards and forwards through very small spaces, by their elastic force. This is evident in the string of a violin, and in the motion of a bell. When, by any force, an elastic string is bent out of its rectilinear direction, as soon as the force ceases to act, it will return to it again, by its elasticity, and acquire such a velocity as will carry it nearly as great a distance in the opposite direction. Here, too, its elasticity sets bounds to its further progress, and brings it back to its former position, and a little beyond in the contrary direction. In this manner, it continues to vibrate backwards and forwards, through small, and constantly decreasing spaces, until its motion is destroyed by the resistance of the medium in which it vibrates, or by friction. In like manner, when the circular edge of a bell is struck by a hammer, the part, which receives the stroke, is forced forward by it, so that the circular shape of the bell's mouth is changed into an oval. But the elasticity of the metal will restore to its former position, the part of the bell which the percussion had forced out of it, and the velocity acquired by the stroke, will carry it some distance in the opposite direction.

The same stroke, which makes a string or bell vibrate, causes it to sound also, and, as the vibrations decay, the sound becomes fainter. When the particles of a sonorous body have been put into motion by percussion, they communicate the motion to the elastic bodies which surround them; these act in a similar manner; and, in this way, the vibratory motions may be propagated to a considerable distance. Elastic bodies, and these alone, are in general capable of producing and propagating sound. The ordinary medium of sound is the atmosphere. When there is no air in contact with the vibrating body, no sound will be heard, unless the body be surrounded with some other elastic medium. Hence in the exhausted re-

ceiver of an air-pump, the sound of a small bell becomes very faint, and, if the air could be entirely exhausted, would not be heard at all. In rarified air, sound becomes weaker; in condensed air, louder. In the air of a diving-bell, condensed by the pressure of the water at a great depth below the surface, the voices of those inclosed in it, it is said, seem much louder than in the open air. This is probably owing to the increased elasticity of the air, occasioned by its condensation. Vibrations are readily communicated to the air, by a sounding body. The air, in immediate contact with the vibratory body, receives a stroke by every vibration, by which it is propelled forward, and by that means condensed. This condensed portion of air, by its elasticity, will expand itself in all directions, so that it will condense the stratum of air, which lies immediately beyond it. This will produce a similar effect, expanding by its elasticity, and condensing the air that lies still further beyond. In this manner, the motion, at first impressed upon the air by the vibrations of the sounding body, will be propagated continually forwards, by a chain of undulations in the air, until it reaches the ear. These condensations of the air, produced by sounding bodies, are called pulses.

Other media besides air, are capable of carrying sound. It is said, that sound can be heard much further under water, than in the open air. A very low sound is easily communicated through wood. Even stone is said to conduct it better than air. Indeed, solid bodies transmit sound with greater rapidity than the air. Hasenfratz and Biot found, that, when the ear was applied to one end of a long wall, and the other end was then struck, two sounds were perceived, one of which first reached the ear applied to the wall, and the other arrived a little later through the air, to the other ear. The body itself may be a conductor of sonorous undulations. Thus, when we touch a sounding body with the ends of the fingers, we perceive a sound caused by a propagation of sonorous oscillations, through the body to the ear. This will

enable us to explain those cases, in which the external ear, and even the external auditory canal, have been wanting, and yet the sense of hearing has existed in tolerable perfection. A case of this kind is mentioned by Heister, in which the hearing was very acute. Another is mentioned by Wright; and the author has been informed, that there is a man now, or recently living at Windsor, Vermont, who has no external meatus, yet can hear tolerably well.

A curious fact, in relation to sound, is that all kinds of sounds, however varying in intensity and quality, are transmitted with equal rapidity through the air, and without being confounded together. The pulsations of the atmosphere, produced by a variety of sounding bodies, appear never to become blended and confounded together; but, each preserves its own individuality, and produces its peculiar impression on the ear. Sound, like light, is capable of reflection. The pulses of sound, falling upon certain bodies which obstruct their progress, experience a repercussion, which forces them back, and produces a reflected sound or echo.

The vibrations of a sonorous body, in order to produce sound, must succeed each other with a certain degree of rapidity. It has been calculated there must be, at least, as many as thirty-two, and not more than twelve thousand, vibrations in a second, in order to be heard by the human ear; but, according to Savart, the limits of audible sounds are much wider. The gravity and acuteness of sounds, depend on the rapidity of the oscillations. The tone produced by very rapid vibrations, is termed *sharp*, or *acute;* that, which is caused by very slow oscillations, is called *grave*. The gravest sound which can be appreciated by the human ear, it is said, results from thirty-two vibrations in a second; the acutest, from eight or twelve thousand, comprehending a range of eight octaves. But, according to Savart, the gravest sound which the ear can appreciate, is caused by fourteen or sixteen vibrations per second; and the acutest audible

sound results from forty thousand oscillations in the same time.

We are less acquainted with the offices of the different parts of the ear, in the function of hearing, than with those of the various parts of the eye, in that of seeing. Of the uses and modes of action of the internal ear, we are almost wholly ignorant. The offices of the external and middle parts, are more intelligible. The cartilage of the ear seems to be designed to collect together, and condense the sonorous undulations of the air, and to direct them into the external auditory passage. It is asserted by Boerhaave, that the external ear is so formed, that all the vibrations of the air which fall upon it, are eventually reflected into the external meatus. This is undoubtedly erroneous. At the same time, the general office of the external ear probably, is, to collect together the sonorous vibrations of the air, and to conduct them into the auditory passage. The pavilion of the ear, however, is not essential to hearing. Many animals, whose hearing is very acute, are destitute of it; and the loss is said to affect the sense but very little.

The rays of sound, as they are figuratively termed, converging into the narrow canal of the external meatus, are conveyed through this passage, and are received by the membrana tympani. This being a tense, dry, and elastic membrane, readily receives the oscillations of the air, and communicates them, both to the chain of small bones, contained in the middle ear, with one extremity of which it is connected, and to the air, existing in the same cavity. The chain of bones, which are elastic substances, propagate the vibrations to the *fenestra ovalis*, and the air of the tympanum, to the *fenestra rotunda*. By the *oval* fenestra which is covered with a membrane, to which the base of the stapes is attached, the oscillations are converged to the fluid of the vestibule; and by the *round fenestra* they are transmitted to the water, contained in the inferior scala of the cochlea. The water of the vestibule propagates the vibrations to that of the superior scala of the cochlea, and the semi-circular

canals; whence the oscillations are directly conveyed to the branches of the auditory nerve, distributed upon all these parts.

It is supposed, that the membrana tympani is made tense or relaxed, by the action of the chain of bones connected with it, which are moved by the small muscles attached to them. This is probably true. But it is still undecided, what circumstances give rise to the changes in the degree of tenseness of the membrana tympani. Bichat supposed, that they are connected with the strength or intensity of the sound. Hence, very loud sounds sometimes occasion a rupture of this membrane; an accident, to which artillery men are liable. Willis mentions a lady, who was unable to hear sounds of ordinary loudness, but who could carry on a conversation in a low voice, if a drum were beat in her apartment.

Others suppose, that the tension varies with the degree of acuteness or gravity of the sounds. Whatever may be the real mode of its action, the integrity, and even the presence of the membrane of the tympanum, are not essential to hearing. It is sometimes punctured without impairing the sense, and, it is said, may even be torn or entirely destroyed, without essentially injuring the hearing. In the elephant, according to Home, the membrana tympani possesses a muscular structure, by which it is capable of contracting, or, of becoming relaxed, according to circumstances. The uses of the chorda tympani are not known.

The small bones of the ear, are supposed to convey the vibrations of sound from the membrana tympani to the internal ear, and to stretch or relax the membranes, to which their extremities are attached. They are not, however, essential to hearing; for, they are sometimes destroyed without deafness being the consequence. It is worthy of remark, that, in birds, which enjoy great acuteness of hearing, three of the ossicles of the ear are wanting.

The office of the Eustachian tube is, to procure the introduction of air into the cavity of the tympanum. It is essential to hearing, the closure of it always

producing deafness. It is a mistake, to suppose, that it conveys the sonorous vibrations to the ear. If a watch be placed in the mouth without touching the teeth, the ticking of it is scarcely perceptible.

The use of the mastoid cells is not known. But they are supposed to perform the same office as the cavity of the tympanum, with which they communicate. In man, in whom this cavity is of considerable dimensions, they are but little developed, forming, in fact, only a kind of spongy tissue; while in birds, in which this cavity is comparatively small, they are of great extent.

Of the respective functions of the different parts of the labyrinth, we are ignorant. Probably they are all necessary to the sense of hearing. The absence of the liquor of Cotunnius, according to Pinel, is one cause of senile deafness.

CHAPTER XXV.

Sense of Smell.

By the sense of smell, we perceive the impression of odors upon the internal surface of the nose. Odors, or smells, are excited by extremely minute particles of matter, which escape from all odorous substances, and are diffused through the atmosphere to a greater or less distance from their source, and, being drawn into the nostrils, in the act of inspiration, and coming into contact with the lining membrane of the nose, give rise to the sensation of smell. Those substances which have no volatile particles, and which consequently do not suffer any to escape into the atmosphere, are termed *inodorous*. Water, though a fluid

and readily evaporating, is nevertheless destitute of smell.

The organ of smell consists of a cartilaginous prominence, of a somewhat pyramidal shape, situated in the middle of the face; divided internally by an elastic partition, into two equal parts; and presenting at its inferior part, two orifices, termed nostrils, which are the anterior openings of two cavities, termed the *nasal fossæ*. Internally it is composed of these fossæ, which commence anterially at the nostrils, and terminate posteriorly by two openings, in the pharynx. Each of these cavities forms an irregular triangular canal, with its base below. On the inner side, they are bounded by the septum narium, and, on the outer, by the turbinated bones, which project into the nasal cavities, and increase their surface, and the extent of the sensible part of the organ. By means of these bones, the nasal canals are divided on each side, into three passages, by which the air may pass from the nostrils into the fauces, and which are severally termed the inferior, the middle, and the superior meatus. Of these, the inferior is the largest, the longest, and the most direct, leading horizontally backwards to the throat. The middle is smaller, but nearly as long. The superior is much shorter, narrower, and more oblique. These canals are so narrow, that a slight thickening of the membrane, which lines them, is sufficient to impede the passage of the air, and sometimes, wholly to obstruct it.

With the two superior meatuses, communicate several cavities, hollowed out in the bones of the face. These are the *maxillary*, the *palatine*, the *sphenoidal*, and the *frontal sinuses*, and the *ethmoid cells*. The frontal and maxillary sinuses, and the anterior cells of the ethmoid bone, open into the middle meatus; and the sphenoidal, and palatine sinuses, and the posterior cells of the ethmoid, into the superior.

The nasal fossæ are lined by the pituitary or schneiderian membrane, a thick, soft and spongy membrane, which adheres to the bones and cartilages of the nose. Its surface presents innumerable minute

prominences, which, by some anatomists, have been considered as nervous papilæ; by others, as mucous crypts; but which Magendie regards, as composed of a tissue of vessels. The pituitary receives a great number of vessels and nerves. These nerves consist of the whole of the olfactory, or the first pair, and of a great number of filaments of the fifth, from the spheno-palatine ganglion, and from the nasal. The distribution of the olfactory nerve is not so extensive as that of the branches of the fifth pair. The former, after passing through the cribriform plate of the ethmoid bone, is distributed over the septum narium, and the surface of the upper turbinated bones; while the filaments, derived from the fifth, are spread over the whole of the pituitary membrane. The sinuses, also, are lined with a thin, soft, delicate membrane, which adheres loosely to the walls of these cavities. It secretes the mucus which smears the pituitary membrane, and, probably, is useful in smelling. This membrane, also, receives some nervous filaments.

The sense of smelling is exercised during inspiration, the air, which is the vehicle of odors, being drawn into the nostrils, and passing through the nasal fossæ, on its route to the lungs, and, perhaps, depositing the odorous particles on the pituitary membrane; especially, in those places where it receives the filaments of the olfactory nerves. As the superior part of the nasal fossæ is that, on which the olfactory nerves are distributed, and where the air has to pass through the narrowest passage, it is here, probably, that the particles are arrested, and excite the sensation of smell. In the act of smelling, we generally shut the mouth, and contract the nostrils, and draw the air in forcibly; so that the current of air is condensed, and its odorous particles concentrated, and directed to the superior part of the nasal cavities.

The organ of smell differs from those of sight and hearing, in the circumstance, that its general sensibility is blended with its peculiar sensibility, as an organ of specific sensation, in the same seat, the pituitary membrane; whereas, in the eye and ear, the two

properties have separate seats, viz. the conjunctiva and the retina in the eye, and the auditory passage and the acustic nerve, in the ear.* Like the nerves of vision and of hearing, the olfactory, according to Magendie, is insensible to contact, and mechanical irritation.

The general sensibility of the pituitary membrane is derived from the branches of the fifth pair, distributed upon it; for, in the four orders of vertebrated animals, the section of this nerve annihilates the sensibility of the membrane. From the moment that this nerve is divided, the pituitary membrane becomes insensible to contact, and to mechanical and chemical irritation; and, what is extraordinary, even to the most powerful and penetrating odors;—from which, it appears to follow, that, though the olfactory is the peculiar nerve of smell, yet, it cannot execute its functions, as such, without the aid of the fifth pair. Indeed, according to Magendie, the olfactory nerves are not essential to the perception of odors; for, the destruction of these nerves, in a dog, was not found to produce an insensibility to *strong* odors; and they have been destroyed by disease, in persons, who have, nevertheless, enjoyed the powers of the sense to the last moments of life; while the destruction of the fifth pair by disease, has been found entirely to abolish the sense of smell, as well as the common sensibility of the pituitary membrane.*

The nose appears to be necessary to the sense of smell. The use of it seems to be, to direct the air, loaded with odorous particles, to the superior part of the nasal fossæ. The loss of it, by accident or disease, is said to be followed by the abolition of the sense; which, however, may be restored by the construction of an artificial nose.

The uses of the sinuses are not fully ascertained. They do not appear to be endued with sensibility to odors; for, neither the injection of odoriferous substances into them, nor exposing them to odorous

* Magendie.

effluvia, in persons affected with fistulous openings into these cavities, has been found to excite the sensation of smell. According to Magendie, the only known use of them is, to furnish a part of the nasal mucus. There appears, however, to be a connection between the capacity of these sinuses and the acuteness of the smell, in the inferior animals, those, which have the largest sinuses, enjoying the sense in the greatest perfection.

An animal may be deprived of smell, by making an opening into the trachea. Bourdon remarks, that those persons, who are unable to pronounce the letters *m* and *n*, generally have the sense of smell imperfect.

CHAPTER XXVI.

Taste.

Taste is the sensation, excited by the impression of certain substances upon the organs of taste, particularly the tongue.

The apparatus of taste consists of the tongue, which is its principal organ, the palate, the internal surface of the cheeks, the teeth, the velum pendulum, and the pharynx; all of which parts are susceptible of impressions of taste, from the contact of sapid bodies. The superior surface of the tongue, however, is the principal seat of this sense, as will appear, upon moving a sapid substance, as a piece of sugar or salt, over different parts of the mucous membrane, which lines the mouth; for, no sensation of taste will be excited, except when the substance is applied to the superior surface of the tongue. Yet, if a little sugar or salt

be placed *under* the tongue, and the latter then be pressed against the floor of the mouth, the taste of the sugar or salt will be distinctly perceived. That the tongue, however, is not the exclusive seat of taste, appears from the fact, that examples of a total loss of the tongue, and even of a congenital deficiency of it, have occurred without being accompanied with a loss or absence of the sense.

The tongue is an organ of extraordinary mobility, extending from the incisor teeth, with which its apex is in contact, backwards to the os hyoides, and the epiglottis, to which its root is attached. It is composed of muscles, which constitute most of its substance, of glands, nerves, blood-vessels, and absorbents, covered by a mucous membrane. This membrane possesses two kinds of sensibility, the one, general; the other, special, or, that by which it is susceptible to impressions from sapid substances. Its cuticle, or epithelium, is very thin; its corpus mucosum, thick and moist; and the cutis vera gives rise to the *papillæ* of the tongue. These are divided into three series, according to their magnitude, viz. the *conical*, the *fungiform*, and the *lenticular*. This last series of glands are the largest, and are disposed nearly in the form of a right angle, near the root of the tongue, with the apex towards the pharynx. The others, of different magnitudes, are disposed promiscuously over the superior surface of the tongue, chiefly at its edges and apex, where the taste is most acute. These last appear to be formed of a vascular and nervous tissue, susceptible of erection.

The nerves of the tongue are derived from four different sources. It receives, 1. several filaments from the spheno-palatine ganglion, especially the naso-palatine; 2. the glosso-pharyngeal; 3. the hypoglossal; and 4. the lingual branch of the fifth pair. Magendie denies, that any of the nerves of the tongue can be traced into the papillæ of the organ.

The twigs, derived from the spheno-palatine ganglions, are supposed to preside over the nutrition, and the secretions of the organ; the glosso-pharyngeal, to be

the source of the general sensibility of the tongue and pharynx, and of their motility, as associated in deglutition; the hypoglossal, as presiding over the proper motions of the tongue; and the gustatory, as the source of its specific sensibility to tastes. The branches of this last-mentioned nerve are distributed, not only to the muscles and mucous surface of the tongue, but also to some of the salivary glands; and, in this manner, they connect the sensations of taste with the secretion of the salivary fluid.

The functions, severally ascribed to these nerves, have been partly determined by experiment. Thus, Magendie states, that, if the gustatory nerve be divided in an animal, the tongue continues to move, but is no longer sensible to the impression of sapid bodies; yet, the palate, the gums, and the internal surface of the cheeks, still preserve their general sensibility. But if the trunk of the fifth pair be divided in the cranium, the power of being affected by sapid bodies, even the most acrid and caustic, is entirely abolished in the tongue, lips, cheeks, teeth, gums, and palate. This total abolition of taste, also, occurs in persons in whom the trunk of the fifth pair is compressed, or altered by disease. In the sense of taste, Magendie remarks, general sensibility is confounded with special; and both properties are evidently derived from the same nerve, the fifth pair.

Pinching the hypoglossal nerve in an animal, immediately after death, occasions convulsions of the muscles of the tongue; while pinching the gustatory, is not followed by contractions of these muscles.

The glosso-pharyngeal is distributed to the roots of the tongue, and the upper part of the pharynx. According to Mayo, the twigs, sent to the root of the tongue, are nerves of sensation only; while those distributed to the upper part of the pharynx, are subservient both to sensation and motion. The tongue is the principal organ of taste; but, the sense exists in various degrees, in different parts of the organ. In general, the sense is most acute at the tip and edges of the tongue, and least so, at its root. Sour and

sweet tastes are most sensibly perceived by the apex of the organ; and bitter and alkaline ones, by its root. The root is also the principal seat of the *after-taste*, which some substances leave in the mouth. It is worthy of remark, that we can never taste well, without bringing those parts of the tongue, on which the impressions are made, into contact with the neighboring parts of the mouth. Though the tongue is the principal organ of taste, we can taste very imperfectly with the tongue alone. In order to exercise the sense perfectly, we apply the dorsum of the tongue to the palate, or its tip, to the palate or the lips.

Different kinds of sapid substances affect different parts of the mouth. Some, for example, act chiefly upon the tongue; some, upon the gums; some, upon the palate, the pharynx, &c., others, upon the teeth. The teeth possess a peculiar sensibility to certain sapid substances; a fact, which we are informed by Magendie, was ascertained by Miel, a dentist of Paris, to be owing to imbibition. Miel demonstrated, that the teeth rapidly imbibe liquids which come into contact with them, and which thus penetrate into the central cavities of the teeth, where their nerves are lodged. The *after-taste*, left by many substances in the mouth, in like manner affects different parts of this cavity. Thus, acrid substances leave an impression on the pharynx; acids, upon the lips and teeth, &c. There are several substances, which, besides exciting the sensation of taste on the tongue, are capable of producing a different impression, which is usually referred to the palate, but, in reality, has its seat in the nasal cavities. These substances, when under the action of the jaws, emit some of their volatile particles, which, during deglutition, ascend into the posterior nares, and excite sensations which belong, not to the taste, but to the smell. These sensations constitute a great part of the *flavor* of sapid substances; and, by closing the nostrils during deglutition, it is easy to ascertain how much belongs to each sense.

Sapid substances, in order to excite the sensation of taste, must either be dissolved before they are re-

ceived into the mouth, or they must undergo a solution in the saliva. This remark, of course, does not apply to liquids and gases.

The sense of taste is subservient to digestion, as that of smell is to respiration. The development of it, in the mammiferous animals, and in man, is said to be, with few exceptions, in proportion to their voracity, and their degradation in the scale of intelligence. Of all the senses, it is the most sensual.

CHAPTER XXVII.

Motion.

The motions of the human body are extremely numerous, various in their kinds, and executed by different kinds of structure. They are generally divided into voluntary and involuntary, or those which are performed under the control of the will, and such as are wholly independent of this power. The voluntary motions, are all executed by organs, which are called muscles, and which are animated by nerves, originating in the cerebro-spinal system. Such are the motions of the limbs and trunk of the body; those of the face, of the eye-ball, of the tongue, of the velum pendulum palati, of the pharynx, of the larynx, and glottis, and the motions of the diaphragm, the only voluntary motions which are not discontinued during sleep, and, perhaps, those of the bladder.

The involuntary motions are of two kinds. One class of them depend on the action of muscles, the other are executed by organs, or tissues, which are not muscular.

The first class of these motions, or those which

depend on the action of muscles, comprehends the following, viz. the motions of the heart, of the œsophagus, stomach and intestines, and of the uterus. To these are added, by some physiologists, the motions of the iris. Over these motions the will has no direct influence. They receive their nerves, not directly from the brain, or spinal marrow, but by ganglions and plexuses, indirectly from both of these organs.

The involuntary motions, which are not performed by muscles, comprise the following, viz. 1. the *vascular*, comprehending the contractions of the arteries, dilated by the blood forced into them by the heart; the motions of the capillary vessels of all kinds, nutritive, secretory, &c. and those of the lymphatic vessels; the motions of the vesiculæ seminales, of the spermatic ducts, of the excretory ducts, of the liver and gall-bladder, and of those of other glands; 2. the *membranous*, including the motions of the skin, which frequently contracts, or shrinks, under the influence of cold, of terror, of gastric sympathy; the vermicular motion of the scrotum, from cold, or other causes; 3. the motions of expansion of the erectile organs and tissues; as the organs of generation, the papillæ of the tongue, the female breasts and nipple, the lips, the ends of the fingers; and certain accidental tissues, as aneurism by anastomosis. To this class of motions, those of the iris are referred by some physiologists.

To these kinds of motion may be added another, viz. communicated motions, as those of the bones, and of other passive organs; those of the brain and spinal marrow, by the action of the heart; the motions of the abdominal viscera, from the action of the diaphragm and abdominal muscles; the motion of the blood, by the action of the heart, and of other fluids, by the action of their respective vessels or reservoirs, and by the contraction of neighboring muscles.

Muscular Motion.

Muscles are fleshy organs, composed of reddish, wrinkled fibres, united together by cellular tissue

into bundles, progressively increasing in size, and the organs, then formed, terminating at both extremities by a fibrous, inert structure, by which they are attached to bones.

These organs may be resolved into fasciculi, or bundles of muscular fibres, each inclosed in its proper sheath of cellular tissue; the primitive fasciculi may be divided into secondary, and these, again, into still smaller bundles, until, at last, we reach the ultimate muscular filament, beyond which the analysis cannot be pursued. Each of these fasciculi has its own sheath of cellular tissue, which serves, at the same time, to connect it with those nearest to it. The whole organ, also, has a common sheath, of the same tissue.

The size of the primitive muscular filament, it is difficult to estimate. According to some physiologists, they are so fine, that, if hollow, they could not transmit the forty-sixth part of a red globule of blood; but, according to Mr. Bauer's observations, their size comes more within the limits of our comprehension. He states, that the globules of blood, when deprived of their coloring matter, and examined by a high magnifying power, appeared to be of the same diameter as the ultimate muscular fibre; and he even supposed he had discovered that the filament was, in fact, composed of a series of globules, disposed in straight lines. The size of the globules, and, of course, the diameter of the ultimate filament, he estimates at about one two-thousandth of an inch. Beclard, Prevost and Dumas, are of the same opinion. Other physiologists, however, differ widely from this opinion. On the whole, the subject is in a very unsettled state. The fibres, it is said, whatever may be their diameter, have the same size and the same form, in all the muscles.

The muscles are plentifully supplied with blood-vessels, which are distributed among the muscular fibres in numerous ramifications, and forming frequent anastamoses. They are also furnished with lymphatics, and with a large apparatus of nerves, which the muscles of voluntary motion receive from the brain, or the spinal marrow.

The muscular fibre is composed, almost wholly, of the fibrin of the blood; a proximate element, which abounds in azote. By the action of the nitric acid upon it, a large quantity of azote and carbonic acid is extricated, and a peculiar fatty substance is formed, which has received the name of *adipocire*. The same change is produced, when large numbers of human bodies have been buried promiscuously in pits; and also by the action of running water upon muscular flesh.

The properties of the muscles are of two kinds; one is *contractility of tissue*, or *animal elasticity*, a property which they derive from the large quantity of cellular tissue incorporated in their substance; the other, is *muscular contractility*, or *myotility*, a property peculiar to the muscular fibre. By virtue of the former property, muscular parts are susceptible of considerable distension, and capable of recovering their previous dimensions, after the distending cause is removed. When any part of the body is moved, the antagonist muscles of the part are put on the stretch. All flexion calls into action the elasticity of the extensors, and vice versâ. This property is particularly exhibited in the muscles which do not act under the influence of the will; as in the hollow viscera, the stomach, intestines, and uterus, which are capable of very great distension, in consequence of the presence of this property in their membranous coats. The same property is also displayed in tumors, in the distension of the abdomen, from pregnancy, or ascites, &c. When a muscle has been subjected to distension, and the distending power is afterwards removed, it gradually recovers its previous dimensions, as appears in the reduction of the abdomen to its natural size, after the evacuation of the water in ascites, and after parturition, and in the shrinking of a part to its original dimensions, after the discharge of an abscess, or the removal of a tumor. The same property occasions the retraction of the two parts of a divided muscle; and Bichat ascribes to it the attitudes which the limbs assume, when they are not influenced by any muscular

contraction. When the vital contractility of the muscles is not exerted, the extensors and flexors mutually balance each other by their contractility of tissue. When a muscle contracts, by an exertion of its myotility or vital contractility, it has to overcome the contractility of tissue of its antagonist; and when the vital power ceases to act upon the former, the contractility of tissue of the muscle, thus put on the stretch, enables it to return to its former dimensions. Hence, when a muscle is divided, besides the spontaneous retraction of its two parts, the contractility of tissue of its antagonist, being no longer counteracted, tends still further to increase the separation. The muscles owe this property chiefly to the large quantity of cellular tissue incorporated in them; but, probably, the muscular fibre itself is not wholly devoid of it.

But the distinguishing property of the muscular fibre, is its *myotility* or *irritability*, or, the vital power of contracting or shortening itself, on the application of a stimulus. In the act of contraction, the two extremities of the muscles approximate, its belly swells, and becomes hard and firm to the touch; its surface furrowed and drawn into wrinkles; and the whole muscle, thicker and shorter. During the contraction, the fibres are agitated with a continual motion, arising from the contraction of some, and the relaxation of others of them; for, though the whole organ shortens itself during its contraction, this is not the case with all its fibres; these do not all contract at the same time. This continual agitation of the fibres during the contraction of a muscle, gives rise to a perceptible sound, which may be heard by the aid of a stethoscope, or, by applying a finger forcibly to the external auditory canal. The sound heard on applying a conch-shell to the ear, is said to be owing to the same cause.

During their contraction, the muscular fibres, which, during the inaction of the muscle, preserved a rectilinear direction, bend themselves in a zigzag form, presenting regular undulations; and, according to Pre-

vost and Dumas, the summits of the angles thus formed, are the points of the muscular fibre, where the ultimate divisions of the nerves which penetrate the muscles at right angles, pass into them.

Many distinguished physiologists are of opinion that a muscle, in contracting, experiences no change of volume. Prevost and Dumas, Blane, Bourdon, Sœmmering, Meckel, &c., are of this opinion. They believe, that the swelling of the belly of the muscle, is exactly compensated by the shortening of the organ.

Some delicate experiments of Glisson, of Swammerdam, of Erman, and Gruithuisen, however, if their accuracy can be depended upon, appear to establish the contrary conclusion. Glisson procured a wide, cylindrical glass tube, closed at the bottom, and having a small funnel-shaped tube inserted into it, near the top. Into the opening of the large tube, the whole naked arm of a strong, muscular man, was introduced, and the mouth of the tube was then closed around it. Water was then poured into the small tube, until it filled all the space round the arm, in the large tube, and stood at a certain height in the small one. Now, when the man strained all the muscles of the arm, the water fell in the small tube; but rose again, when the muscles were relaxed. Rudolphi regards this experiment as perfectly satisfactory, notwithstanding the objections which Haller and others have brought against it. Swammerdam, also, found, that the contractions of a frog's heart, occasioned a sinking of the water in the small end of a thin glass tube, drawn out at one extremity.

In like manner, Erman and Gruithuisen found, that when a piece of an eel's tail, or of a frog's thigh, was introduced into a glass tube, provided with a small side tube, and was then subjected to the galvanic or electric shock, whenever the closure of the chain produced a muscular contraction of the part, the level of the water in the small tube was sensibly lowered.

According to Rudolphi, the few experiments, in which no sinking of the water has been observed during the contraction of muscles, have been too

coarse and inaccurate to warrant any conclusion. The essence of muscular contraction, he supposes to consist in a condensation of the muscular substance, by which it contracts on all sides.

By other physiologists, the diminution of the volume which a contracted muscle experiences, admitting the reality of the phenomenon, is ascribed to the compression of the cellular tissue, to the pressing out of the venous blood of the muscle, and the obstruction, occasioned by the contraction of the muscle, to the entrance of arterial blood.

A muscle is able to preserve a state of contraction only a limited time. Sooner or later, the effect ceases, and the muscle returns to its former state, or becomes relaxed. It is assisted, probably, in recovering its former dimensions, by the power of its antagonists. The duration of the contraction is different, according as it is excited naturally, or artificially. When excited by an act of the will, the contraction can be continued for a considerable time; but the effort at last becomes painful and difficult, and can no longer be maintained. When the voluntary muscles contract under the influence of morbid irritation, the contraction is sometimes of a permanent kind, as in tetanus, and trismus. But, if a muscle be exposed to direct irritation of a mechanical kind, or to galvanism, the contraction is soon followed by relaxation, though the application of the stimulus be continued.

The velocity of muscular contraction produced by an act of the will, is very variable, and is regulated by volition. The possible celerity of muscular action, depends much on exercise, and may be almost indefinitely increased by practice. Haller computed, that the elevation of the leg of a race-horse, in the act of racing, is performed in the one-seventieth part of a second. He also calculated, that, in the most rapid motions of a man, the *rectus femoris* is shortened three inches, in the two hundred and eightieth part of a second. But he remarks, that the muscles employed in articulation, execute the most rapid contractions. He states that he himself, pronounced five hundred

letters in a minute; a task of little difficulty, as any one will find, who will undertake it.

A muscular fibre, in a state of strong contraction, is from one-fourth to one-third shorter than when in a state of relaxation. The degree of shortening appears to be in the ratio of the length of the fibræ, and the degree of its contractile energy.

The power of muscular contraction is very great, though it is difficult to appreciate it. The efforts produced by muscular contraction, are sometimes very extraordinary. The extensors of the knee have been known to fracture the patella, by a sudden and violent contraction, during the operation of lithotomy. The same accident has taken place during a fall, in consequence of a sudden and violent contraction of the extensor and flexor muscles, simultaneously, as if the mind, in its terror and confusion, had issued orders for both sets of muscles to contract at the same instant. Rudolphi mentions a fact, which may illustrate the great force of muscular contraction, even in feeble persons, when excited by morbid irritation. It was a case of chorea, occurring in a girl, twelve years of age. In an attack of opisthotonos, which she experienced, several grown men stood on her abdomen, to counteract the curvature of the body, produced by the spasms, but without the least effect.

If a person with a burden on his back, stands on tiptoe, on one foot, the whole weight of the body, and of the burden, is supported by the extensor muscles of the foot. In jumping, these muscles project the body with immense force.

The power of muscular contraction depends, partly on the organization of the muscles, particularly the volume and number of their fibres, and partly on the degree of the excitation which they receive, or the force of the stimulus which acts upon them. The influence of the brain has a great effect in increasing the energy of muscular contraction. The degree of power exerted in the voluntary motions, depends in general on the will, which adapts it exactly to the effect intended to be produced. If we merely raise

the arm, or elevate a very small, or a very heavy weight, the force of the muscular contraction is precisely adequate to the effect. When the brain is excited to preternatural energy, by causes foreign to the will, as in maniacs, in persons transported with passion, and in the delirium of fever, the power exerted by the muscles, even in persons of a feeble or delicate organization, is sometimes very great. The excitability of the nervous power, and the strength of the muscular organization, are frequently in the inverse ratio to each other. Women and children, who have comparatively feeble muscles, possess very excitable nervous systems; and, on the contrary, brawny, and athletic men, having strongly marked, prominent muscles, frequently possess but little nervous excitability.

The strength of a muscle is much greater in a living state, than after death. A dead muscle will be lacerated by a much smaller weight appended to it, than the muscle could lift with ease during life. The muscular part of a dead muscle is torn through, by a less weight than the tendinous. But, in the living state, it is the tendon which is the first to give way. Thus, the tendo achillis is sometimes ruptured by the force exerted by the muscular fibres of the gastrocnemii, and soleus muscles.

The power of contraction of the muscles is much weakened by want of sleep, by fatigue, excessive heat, evacuations, and the abuse of stimulants, especially alcoholic drinks and opium. Even a moderate draught of wine will frequently produce a feeling of weakness in the muscles, and very sensibly impair their powers of exertion. On the other hand, the muscular power is recruited by rest, sleep, plain food, and bathing. The muscles of voluntary action, like the other organs of animal life, are subject to a complete periodical rest, every twenty-four hours.

The phenomena of muscular contraction require certain conditions, without which they do not take place. These are, the action of some stimulant, or excitant, without which, the muscle remains in a state of relaxation; the presence of vitality in the muscle;

the integrity of its organization; and the uninterrupted communication of its vessels and nerves with the centres of the circulating and nervous systems. Without the influence of some excitant, the muscles remain without contraction. The excitants which may rouse a muscle to action, are of different kinds, as, for example, *the will;* certain stimulants, applied directly to them, or to the nervous centres, with which they communicate, or to the nerves which form the channel of communication. A muscle, deprived of its supply of arterial blood, contracts very feebly. If its communication with a nervous centre be interrupted, it is withdrawn from the influence of this centre; and if irritations, applied directly to it, excite contraction in it, it is because they act upon its inherent irritability, or upon the nerves incorporated in its substance. The irritability of a muscle is generally diminished by extreme cold or excessive heat, by the direct application of opium and some other substances to it, and by over-distension.

It is remarked, above, that the presence of vitality is a necessary condition of muscular contraction. It is to be observed, however, that certain of the muscles, both voluntary and involuntary, in some instances, continue to act some time after death. This is true, particularly of the heart and intestinal canal; but nearly all of them may be excited to contraction by artificial means. In the amphibia, especially, as the frog and the salamander, the muscular irritability continues a long time after death. In birds, on the contrary, the irritability of the muscles is very soon extinguished, ceasing much earlier than in the mammalia and the human species.

According to Nysten, the duration of the contractility of the muscles after death, in the different classes and orders of animals, is in the inverse ratio, to the degree of energy with which the muscles are endued during life. To this principle, however, there are many exceptions.

Some of the muscles lose their contractility much sooner than others; and, according to the same physi-

ologist, the order in which this property becomes extinguished after death, in different muscles in the human body, is as follows:—

1. The left ventricle of the heart, loses it first.

2. The stomach and intestines, next; the large intestines, from forty-five to fifty-five minutes after death; the small intestines, a few minutes later; and soon after, the stomach.

3. The urinary bladder, which sometimes loses its irritability as soon as the stomach, but, frequently, somewhat later.

4. The right ventricle of the heart, whose motions, in general, continue more than an hour after death.

5. The œsophagus, which ceases to contract about an hour and a half after death.

6. The iris, whose irritability is extinguished, in many cases, fifteen minutes later than that of the œsophagus.

7. The muscles of animal life. In general, the muscles of the trunk lose their contractility sooner than those of the limbs; and the muscles of the lower limbs, earlier than those of the superior.

8. The auricles of the heart. But the right auricle loses the power last; so that, of all parts of the heart, it retains its contractility the longest. The right auricle is, therefore, truly the *ultimum moriens*, as it was called by Galen and Harvey. In experiments on dogs, it was frequently found, that the *left ventricle* lost its irritability in half an hour after death; while that of the *right auricle* continued eight hours.

The venæ cavæ, where they join the right auricle, are evidently muscular, and are irritable, like the muscles themselves. No contraction can be perceived in the arteries by the application of a stimulus.

The stimuli, which produce vital contraction of the muscular fibre, are of various kinds. The muscles belonging to animal life, or those of voluntary motion, contract under the influence of the will, or by the energy of the brain, acting through the medium of the nerves. But there are, also, certain pathological causes, by which the brain may be excited to react

upon the muscles of voluntary motion, without the intervention of the will. Such are local irritations, acting directly upon the brain; as, for example, local injuries, morbid determinations of blood, inflammation of the organ, preternatural excitement of the brain, from insanity, violent passions, &c. In other cases, the brain may be excited by sympathy with some other suffering organ, and react upon the voluntary muscles, producing involuntary contractions, or convulsions. Intestinal irritation, from worms and other causes, and uterine irritation, may thus indirectly give rise to spasms of the voluntary muscles.

In general, the energy of muscular contraction is increased by causes which excite the brain, as wine, opium, passion; and, on the other hand, it is diminished by causes which exert a sedative influence over the cerebral energy, as terror, which may induce an almost paralytic weakness.

The energy of the brain is transmitted to the voluntary muscles by the medulla spinalis and nerves; and irritations, applied to the spinal cord, influence the muscles, which receive their nerves below the affected point, precisely like irritations applied to the brain. Irritation of this column of nervous matter excites convulsions, and compression of it produces paralysis of the muscles. The higher up the spine the injury is inflicted, the greater is the number of muscles affected, and the greater is the danger to life. If the lumbar portion of the spinal marrow be injured, the muscles of the pelvis, and of the lower limbs, become paralyzed. If the dorsal portion be injured, those of the abdomen are affected, and respiration begins to be embarrassed. If the spinal cord be injured, above the origin of the phrenic nerves, the diaphragm is paralyzed, and respiration immediately ceases. Irritation of the nerves, by mechanical or chemical agents, causes involuntary contraction of the muscles supplied by these nerves, and when several muscles are supplied by a single nerve, irritation of this nerve will convulse them all. So, if a nerve be compressed or divided, the muscles, supplied by it, will no longer contract under the in-

fluence of the will. They will become paralyzed, not from a loss of their proper irritability, but from the absence of its usual excitant. For, they may still be stimulated to contraction by some irritation, applied directly to them.

It appears, therefore, that the proper stimulus of the voluntary muscles is, the energy of the brain, which may be determined by one of three causes; 1. an act of the will, which is the usual and natural excitant; 2. some impression made upon the brain, independently of the will; and 3. sympathy with some other organ, as the alimentary canal, or uterus, affected with morbid irritation. In the two last cases, not only is an act of the will unnecessary to produce the muscular contraction, but it is, also, wholly unavailing to prevent it. A healthy action of the nerves is also necessary to the effect; and irritation of these organs will produce involuntary contractions of the muscles, precisely like irritation applied to the brain, or the spinal cord.

A physiological state of the muscles themselves is necessary to their contraction. If these organs be inflamed, bruised, or excessively distended, they are unable to contract. A due supply of arterial blood is also necessary. If venous instead of arterial blood be transmitted to them, it renders them incapable of executing their functions.

But other causes, besides the influence of the brain and nervous system, may excite contractions of the voluntary muscles. Thus, mechanical and chemical stimuli, of various kinds, applied directly to them, as pricking or cutting them, &c., the application of acids, alkalies, electricity, galvanism, will excite them to contract. If a muscle be laid bare in a living animal, it contracts with a kind of tremulous motion. The same effect is produced, if a muscle be wholly removed from its connection with the living parts of an animal, and subjected to irritation. It is not necessary to irritate the whole mass, in order to produce the effect; for, the irritation of a few fibres, by a

puncture, is sufficient to exite contraction in the whole organ.

It is a *vexata quæstio* in physiology, whether the muscles derive their power of contraction from the nerves, which are incorporated in them, or whether their irritability is an inherent and specific property of the muscular fibre. Haller contended for the latter opinion, and accordingly termed this property, the *vis insita*, and the *vis musculorum propria;* while many distinguished physiologists have maintained the other. It is, perhaps, impossible to decide this question. But it seems probable that the muscular fibres and nerves are, both of them, factors of this power. It seems impossible that contractility of the muscles can be derived from the nerves, because the nerves possess no such power themselves. They cannot give what does not belong to them. But, on the other hand, as the muscles are universally supplied with nerves, and as it is impossible to conceive that any stimulus can be applied to a muscle without affecting some of the nerves incorporated in its substance, it is difficult not to suppose that the nerves are, in some mode or other, essential to the phenomena of muscular contraction. Any muscle may be excited to contraction, by irritating the nerve which goes to it. It is true that a muscle, or part of one, even when removed from its connection with the living body, is sometimes observed to contract; but it is to be remembered, that a large quantity of nervous matter exists in it, and, perhaps, is essential to the phenomenon. Admitting the irritability of muscles to be an inherent and independent property, it is still true, that all the muscles, without exception, require an influx of nervous power to excite them to contraction. This nervous power may be transmitted from the brain, or it may be directly excited by irritations, applied to the nerves, or to the muscles themselves, when, undoubtedly, they act upon some of the nervous fibrils, which are diffused throughout the substance of the muscles. Tiedemann supposes that the nerves, diffused throughout the substance of the muscles, impart to the latter a sus-

ceptibility to the action of their excitants, or the aptitude to be affected by them; or, that the stimuli, which excite muscular contraction, act immediately upon the nerves distributed in the muscles, and produce the action of the latter only through the medium of these nerves.

The muscles of animal life, or those which act under the influence of the will, receive their nerves chiefly from the spinal marrow. These are the muscles which move the trunk and upper and lower extremities. Those which are chiefly designed to express the emotions of the mind, and may be considered as holding a higher rank in the scale of organization, receive their nerves directly from the brain. These are the muscles of the face and eyes.

The muscles of vegetative life, on the contrary, receive their nerves chiefly from the ganglionic system.

The essence, or immediate cause of muscular contraction, is unknown. Various hypotheses have been formed to explain it, but no knowledge is obtained by conjecture. One of the most ingenious and plausible theories, which have been formed on the subject, is that of Prevost and Dumas, who regard muscular contraction as an electrical phenomenon; an opinion founded partly on microscopical observations. These physiologists first examined, with a microscope, the mode in which the nerves penetrate into the muscles, and are distributed in them; and they observed that the nervous filaments pierced the muscular fibres, in a perpendicular direction, or at right angles to the axis of the fibres. They also took notice, that no nervous filament actually terminated in the muscles, but that their ultimate ramifications embraced the muscular fibres, in the form of loops, and then returned to the trunks which had furnished them, or went to unite with some nervous trunk in the vicinity. Upon examining, with the same microscope, the muscles at the time of their contraction, they observed that the muscular fibres which composed them, suddenly contracted, or bent themselves in a zigzag

manner, and presented a great number of regular undulations; the angles of flexion varying according to the degree of contraction. These bendings or angles, were observed always to take place at the same points in the muscular fibres, and to these flexions the contraction of the muscle was owing. They observed, finally, that the summits of these angles corresponded with the points where the nervous filaments entered the muscle. These observations led them to infer, that the shortening of the muscular fibres was owing to an attraction between the nervous filaments which entered them; the effect of which would be to approximate the points where these filaments entered the muscle, towards each other, and thus to cause a wrinkling up, or contraction of the muscular fibres. The approximation of the parallel nervous filaments towards one another, they ascribed to a galvanic current, passing through these filaments, in conformity to a law, discovered by Ampere, that two galvanic currents, moving in the same direction, are attracted towards each other. This theory supposes what many physiologists of the present day are disposed to look upon as probable, viz. that the nervous influence is some modification of the galvanic fluid. Whenever a current of nervo-electric fluid is conveyed along a nervous trunk to a muscle, as it must enter the fibres of the latter in the same direction, by parallel nervous filaments, these filaments, according to the law of Ampere, will be attracted towards each other, and will draw the summits of the angles of flexion of the muscles towards one another, producing a shortening of the muscular fibres, in a zigzag form.

Most of the muscles of voluntary motion are long and slender, terminating, at each extremity, in tendinous chords, by which they are attached to the bones, on which they act, and which they move, in the manner of levers. The locomotive muscles, however, act under great mechanical disadvantages, in consequence of which there is a great expense of force to bring about an inconsiderable effect. These unfavorable circumstances, in the disposition of the muscles, are

chiefly two, viz. 1. that they are inserted into the bones near the centres of motion, while the weight they have to move is usually applied to the extremity of the lever. For, the bones may be considered as levers, the joints as fulcra, or centres of motion, and the muscles as moving powers; and it will follow, from the laws of mechanics, that the nearer the attachment of the muscle is to the joint, or fulcrum, the less effect it will produce in moving the bone, and vice versâ.

It is inaccurate, however, to call this a loss of power. There is, in fact, no loss of power in the case; but, a greater force must be applied to the short end of the lever, in order to move the long extremity, because the latter, moving through a greater space, must move with a greater velocity than the short end; and, according to a well-known principle of mechanics, the forces, on the two opposite ends of a lever, will balance each other, if the one be as much greater than the other, as its motion is slower. The opposing forces, on the two ends of a lever, are to each other, inversely, as their respective velocities, or distances from the centre of motion. The object aimed at, by this arrangement of the muscles, was, to give to the extremities a great range and freedom of motion, without making the limbs unwieldy or clumsy; and this object is perfectly attained, by inserting the tendons of the muscles near to the joints, which are the fulcra, or pivots, on which the bones move. In the human arm, the deltoid muscle, by contracting less than an inch, raises the elbow twenty inches; and, of course, if it overcomes a resistance of fifty pounds, at the elbow, it must itself be acting with a force twenty times as great, or a force of one thousand pounds; this greater force, exerted by the moving power, being exactly compensated by the greater velocity and range of motion of the resistance overcome.

2. A second unfavorable circumstance under which the muscles act, is, that they are attached to the bones at very acute angles, so that their line of action is very oblique. If they were inserted at right angles, then

their whole force would be effectively exerted in moving the parts. If, on the other hand, they were exactly parallel to the bones to which they are attached, their whole force would be lost, and no motion of the bones would be produced by their contraction. The nearer the direction of the force approaches to a perpendicular to the lever, the greater will be the effect produced in moving the latter; and the nearer it approaches to a parallel, the greater will be the proportion of force expended without effect. In the human body, the line of action of the muscles forms a very acute angle with the bones which are moved by them; and, in consequence of this unfavorable direction, there is a great loss of power.

The various attitudes and motions of the human body, are owing to the contractions of the voluntary muscles, acting upon the bones to which they are attached. The human body maintains the erect position, by the powerful action of numerous muscles. If the body, in an erect position, be left to itself, and no muscular effort be made to sustain it, the head will incline towards the chest, the chest will flex itself on the pelvis, the pelvis on the thighs, the thighs on the legs, and, finally, the legs on the feet. It is, therefore, necessary, in order to maintain an erect position, that the muscles of the back of the neck should support the head; the muscles of the back, the chest; the muscles of the loins and buttocks, the pelvis; those of the pelvis, the thighs; those of the thigh, the leg; and those of the calf of the leg, the foot. The attitude of standing, therefore, requires the action of a large part of the muscles of the body. It is further to be observed, that the equilibrium of the body is never perfect and steady. It is always more or less vacillating and unsteady. It is impossible to poise a dead body, supposing it to be rigidly extended, so exactly upon the two feet, as that it will retain an erect position. There is a constant *nisus* in the muscles of the body, to keep it in such a position that the centre of gravity, which is high, shall be constantly directly above the narrow base, formed by the two feet and the space

between them. To produce this effect, a constant change, in the degree of action of different muscles, is necessary.

The head is not poised exactly upon the spine, but its anterior part preponderates, so that it has a tendency to incline forward; and, in order to counterbalance this tendency, several strong muscles are placed at the back of the neck, as the splenius, the complexus major, and minor, the trapezius, and the posterior recti muscles. The action of these muscles, by tending to draw the head backwards, counteracts the preponderance of its anterior part.

The spine, also, has a tendency to incline forward, partly in consequence of its having to support the weight of the head, which has the same inclination, and partly because, anteriorly, there are connected with it the thorax and abdomen, and the ponderous viscera contained in them, which powerfully increase the tendency to incline forward. To counterbalance this inclination, there are several strong muscles, which occupy the vertebral fossæ, as the sacro-lumbalis, longissimus dorsi, multifidus spinæ, &c., muscles which extend from the sacrum to the inferior vertebræ, and from the inferior vertebræ to the superior. The fixed point of these muscles is below. The lumbar vertebræ are maintained in a straight position upon the sacrum, and, when fixed, they become a point of support to those above, and so on successively, from below upwards. Each vertebra is then a lever, of the first kind, the power being at one end, viz. at the spinous or transverse apophyses, to which the muscles are attached; the resistance consisting in the weight of the thorax and abdomen, being at the other, and the fulcrum between the two, at the articulation of the vertebræ.

The resistance acts upon a longer arm of the lever than the power, since the former is measured by the length of the ribs, and the latter by that of the spinous apophyses of the vertebræ. But this disadvantage is compensated by the circumstance, that the muscles are inserted perpendicularly into the bones on which

they act. Considering the vertebral column as a single lever, it may be referred to the third kind, in which the power is between the fulcrum and the resistance; and as it is at the inferior part of the spine that the power has the greatest resistance to sustain, since it has to support almost the whole length of the lever, it is here also, that the muscles have the greatest thickness and strength, and the spinous and transverse processes are the largest.

The pelvis is immovably articulated with the sacrum, and, of course, no muscular effort is necessary to support these parts in their fixed position. But below, the pelvis rests upon the heads of the thigh bones, by the two cotyloid cavities. The pelvis, thus forming a single lever with the spine and the head, tends to fall forwards, partly in consequence of the tendency of all the superior parts of the body to incline in this direction; and partly from the oblique position of the pelvis. To counteract this inclination, several strong muscles contribute, as the glutæi muscles, the abductors of the thigh, &c., the action of which tends to keep the pelvis and the trunk in the same vertical line with the thigh. If the fixed point of these muscles is below, at their attachment to the thigh bone, their contraction must draw the pelvis and trunk backward, and thus counteract the inclination forwards of the superior part of the body. The trunk of the body, with the pelvis and head, may represent a lever of the third kind, the fulcrum being at one extremity, viz. the ileo-femoral articulation; the resistance, which consists in the weight of the trunk, at the other; and the power, between the two, at that part of the pelvis to which the muscles are attached. As the lever is a long one, extending from the vertex to the acetabular cavities, a great force is requisite to overcome the resistance, and, accordingly, the muscles destined to this office, are very bulky and powerful, constituting the immense fleshy mass of the buttocks.

The thigh is articulated with the leg by too small a surface to poise the body upon without the aid of

muscular action. From the structure of the femoro-tibial articulation, and the manner in which the pelvis presses upon the thigh bone, the lower extremity of the latter is forced forwards, flexing the leg upon the thigh. The extensors of the leg, the rectus femoris, and the triceps extensor cruris, counteract this tendency. Their lower extremity being attached to the tibia as a fixed point, and their superior to the upper part of the os femoris, they maintain the femur, and with it all the rest of the body, in the same vertical line with the tibia. These muscles also act upon a lever of the third kind. The fulcrum is at one extremity, viz. the tibio-femoral articulation; the resistance, which is the weight of the body, at the other; and the power is applied between them, at the place of insertion of the muscles.

The weight of the body and thighs is transmitted to the feet by the tibia. The superincumbent parts have a tendency to fall forwards, turning upon the ankle-joint as a movable hinge; but they are supported by the muscles of the calf of the leg, viz. the gastrocnemii and soleus, the peroneal and the tibialis posticus, which have their fixed point in the feet. These muscles act upon a lever of the third kind; for, the fulcrum is at one extremity, viz. the tibio-astragalar articulation; the resistance at the other; and the power between them, at the place of the superior attachment of the muscles.

The foot rests upon the ground by a surface of considerable extent, and is pressed firmly against it by the weight of the body, and also adheres to it, by the action of certain muscles, viz. the common and proper flexors of the toes. The contraction of these muscles tends to fix the toes firmly to the ground, and to give greater firmness to the position. The use of shoes destroys much of the effect of the action of these muscles.

Standing upon one foot, is more difficult and much more fatiguing. The base of support is reduced to the dimensions of one foot alone, and the centre of gravity has a lateral inclination towards the unsup-

ported side of the body. The muscles, whose action counteracts this inclination, are the glutœi, the gemelli, the tensor vaginæ, the obturators, the quadratus femoris, and the pyramidalis. Strong efforts of these muscles are necessary to maintain the line of gravity within the narrow dimensions of the base.

Walking.—In man, this is the most common kind of locomotion, and it consists in placing one foot before the other alternately, and carrying the body forward with it. In this kind of progression, the line of gravity is incessantly transferred from one of the lower extremities to the other, without the body being left a moment unsupported, as it is in jumping and running.

The mechanism of it is as follows: the person being supposed to be standing on the two feet, placed by the side of each other, he first inclines his body towards the left, so as to throw his weight upon the left leg. Then resting with his whole weight upon this leg, he bends the right, at its different joints, flexing the thigh upon the pelvis, and the leg upon the thigh, so as to shorten the limb, and to detach it from the ground. Raising the right limb, he then advances it forward, and applies it to the ground. At the same time, he transfers the line of gravity of the body from the left leg to the right; and in doing so, he moves the body obliquely forward and to the right, until its weight rests upon the right foot. At this moment the left leg is extended behind him, resting upon the toes. This, in its turn, is raised from the ground and advanced forwards of the right, by a similar movement; and, in this manner, the motions of the two legs, carrying the body with them, alternate with each other as long as the progression continues.

Running is an accelerated progression, which, in its mechanism, is intermediate between walking and leaping. The lower extremities are advanced, one before the other alternately, as in walking, transmitting the weight from one to the other. But the limb which is left behind projects the body, as in leaping, to the other, which is in advance of it, so that the

line of gravity is transported to the forward leg before the foot touches the ground, and, for a moment, the body is suspended, unsupported, in the air.

Jumping or *leaping*, is a rapid motion, in which the body is raised from the ground and projected to a certain height in the air, and afterwards, by its own weight, falls to the ground again. In order to execute this motion, the person first bends all the articulations of the body, from the head to the feet, flexing the head forwards upon the neck, the spine upon the pelvis, the pelvis upon the thighs, the thighs upon the legs, the legs upon the feet, and the feet upon the toes; for the heel does not touch the ground. To this general flexion succeeds a sudden extension of all these joints, the effect of which, in consequence of the reaction of the ground, is to give a projectile motion to the body upwards and forwards, which overcomes its weight, and, consequently, raises it from the ground.

Springing or *jumping* with one foot, is called *hopping*. The mechanism is the same as that of leaping, except it is performed by one foot only.

Swimming.—This is a kind of springing or leaping in the water. The body, being extended along the surface of the water, the lower extremities are flexed and drawn up towards the nates, and are then suddenly extended, as in the act of leaping. The water, forcibly struck by the feet, yields, in part, to the shock, but still resists and reacts against the body sufficiently, to impel it forward, with a force superior to its weight. The feet, which had been separated from each other in the act of extension, are then brought together again, in a line, behind the body; and the hands, in their turn, are pushed outwards and backwards, describing two arcs of circles, cutting the water in their course, but experiencing resistance and reaction sufficient to aid in impelling the body forward. These motions of the hands and feet succeed each other alternately; and the body receives from them an impulse sufficient to counterbalance its own weight and keep it above water, and even to give it a pretty rapid motion forwards.

A remarkable fact, with respect to the voluntary muscles, was ascertained by Mr. Hunter, viz. that these muscles, after contracting to their utmost extent, might gradually acquire a new sphere of contraction. This fact was ascertained by the following case, mentioned by Mr. Abernethy. A lady, who had suffered a fracture of both knee-pans, came to London many years after the accident, and consulted Mr. Hunter. After ascertaining that the union between the ends of the two patellæ was of an unyielding nature, he found that the muscles, attached to the patella, were unable to move the retracted part, because they had already withdrawn it to the utmost extent of their original power. Hunter saw no reason why muscles, so circumstanced, might not acquire a new sphere of contraction, so as to be able to act upon the patella, and extend the leg. In order to put his ideas to the test, he had the patient placed in a sitting posture, upon a table, with her limbs hanging over it, and suffered to dangle, like the pendulum of a clock. At first she was unable, by any exertion of the extensor muscles, to check the motion of flexion under the table, or to prolong or increase, the motion of the limb in the opposite direction. But, by practice, she gradually acquired the power in a certain degree. Hunter then added weight to her limbs, to increase the demand for muscular exertion; and, by degrees, the patient, at length, recovered the power of extending the legs upon the thighs, and the ability to stand and walk.

It has already been observed, that the muscular system may be divided into two great sections, differing from each other in their organization, vital properties, external form and functions. In one of these, motion is produced under the influence of the will; in the other, it is wholly independent of this power, and is determined by the application of peculiar stimuli. In some of the muscles, these two characters are united. Hence, the muscles have been divided into voluntary, involuntary, and mixed.

Organic Muscles.

The muscular system of organic life, or the involuntary muscles, differ, in many important particulars, from the voluntary muscles, or those of animal life. They are by no means so extensively distributed over the body as the other class, and they constitute a much smaller portion of its bulk. These muscles are found, principally, in the chest, abdomen, and pelvis, forming a considerable portion of the hollow viscera contained in these cavities. In the thorax are the heart and œsophagus; in the abdomen, the alimentary canal; in the pelvis, the bladder. This system, therefore, exists principally in the interior of the body, removed from the action of external agents. No part of it, however, exists in the head.

The fibres of the muscles of animal life, are arranged in straight lines. In those of organic life, on the contrary, the fibres are generally curved, so as to form cavities, or canals, of various shapes. These muscles are never attached to bones, nor do they terminate in tendons. They are never collected into insulated bundles of parallel fibres, like those of animal life, but they are generally arranged in thin membranous plates, forming broad muscular strata. The fibres are not disposed in an uniform direction, but decussate or cross one another, at various angles and in different directions. Hence is derived their power of closely embracing their contents, of contracting upon them, and even of obliterating their own cavities.

These muscles possess great animal elasticity, or extensibility and contractility of tissue; that is, they are susceptible of great distension by an accumulation of their contents, or from other causes, and they have the power of recovering their former dimensions after the removal of the distending cause. Thus, the alimentary canal admits of great distension, from an accumulation of feculent matter, or the evolution of gas; and the urinary bladder, from great collection

of urine. The bladder may be distended to three or four times its ordinary capacity, without losing its power of contracting. But, by excessive distension it is liable to become paralyzed, in which case its muscular coat loses its power of contraction.

The chief seat of the elasticity of the hollow viscera is the cellular tissue, which enters largely into their structure. Perhaps the muscular fibre itself may possess this property in some degree.

The antagonists of the hollow muscles are their contents, and as long as they are distended by these, their contractility of tissue cannot be exerted; but, when their contents are removed, they contract, by this power, into a small volume. It is to be observed, that the contents of the hollow viscera are not expelled from them by their contractility of tissue, (which merely enables them to resume their former dimensions,) but, by their vital and muscular contractility, which produces the effect by a series of contractions and relaxations. When the muscular contractility of a hollow organ has expelled its contents, its elasticity enables it to contract to its former volume.

These muscles differ remarkably from the voluntary muscles, in the nature of the cause which excites them to contraction. Their peculiar stimulus is not the nervous or cerebral influence. They receive their nerves, not from the brain or spinal marrow, but from the ganglions; and the influence of the brain, whether determined by an act of the will, by impressions made directly on the organ, or by sympathy, exerts but little power over the contractions of these muscles. Every one is aware that the functions of organic life, the actions of the heart and arteries, those of the stomach and intestines, are not, in the slightest degree, influenced by the will; that they can neither be accelerated, nor retarded, nor suspended, by any effort of voluntary power. In like manner, irritation of the brain has no effect upon the action of these muscles. The circulation of the blood can be carried on without the aid of the brain, as is exemplified in

the case of acephalous fetuses.—And it is well known, it can be kept up artificially after decapitation.

The peculiar stimuli of these muscles is that of their respective contents. Thus, the blood is the natural excitant of the heart and blood-vessels; alimentary and feculent matter, that of the stomach and intestines; the urine, that of the bladder, &c. They are also sensible, though in very different degrees, to artificial stimuli, applied directly to them.

In general, they are less sensible of the stimulus of galvanism than of mechanical irritation. And they are much less under the nervous influence than the muscles of voluntary motion.

CHAPTER XXVIII.

Of the Voice.

The organ of the voice is the larynx, a cartilaginous box, placed between the os hyoides and the trachea, and communicating below, with the air-tubes of the lungs, and above, with the mouth and the nasal passages. It is composed of five cartilages, viz. the *thyroid*, the *cricoid*, the two *arytenoid*, and the *epiglottis*, which are movable upon one another by the action of several muscles. The whole larynx may also be elevated towards the chin, or depressed towards the sternum, by the action of numerous muscles.

The principal part of the larynx is the superior. At its upper and back part, are two small pyramidal bodies, called the arytenoid cartilages. These have a sliding motion, in every direction, upon the cricoid cartilage, to which they are attached by a strong

ligament. On the inside of the larynx, there are two ligaments, formed of elastic and parallel fibres, and extending forward from the anterior part of either arytenoid cartilage to the thyroid cartilage, where they meet. These are called the *chordæ vocales*, or the vocal ligaments. The opening between them is the entrance into the windpipe, and is called the *glottis*, or the *rima glottidis*. This narrow chink is capable of being enlarged, contracted, or wholly closed. Immediately above these two ligaments are two small pouches, termed the ventricles of the larynx, and above the ventricles are situated two other ligaments, formed of mucous membrane, and extending between the arytenoid and thyroid cartilages, above the *chordæ vocales*. So that the ventricles of the larynx are situated between these ligaments and the vocal chords.

All the modifications of the voice are produced by the air, passing out of the lungs through the larynx. The sound is occasioned by the vibrations of the vocal ligaments. According to Magendie, the gravity or acuteness of the sound depends on the greater or less approximation of the arytenoid cartilages towards each other. But Mayo remarks, that the pitch of the voice has no reference to the size of the aperture between the vocal chords, nor to any alteration of their length, but depends solely on their *tension*, and, consequently, on the frequency of their vibrations.

The larynx is raised by the action of several muscles, as the digastric, the genio-hyoid, the genio-glossal, the stylo-glossal, the stylo-hyoid, the stylo-pharyngeal, and the hyo-thyroid. During its elevation, the glottis is contracted, and the vocal ligaments approximate nearer together, and the pitch of the voice is raised. On the contrary, the sterno-hyoid, sterno-thyroid, coraco-hyoid, and crico-thyroid, depress the larynx; and, at the same time, the arytenoid cartilages are separated from each other, and the glottis is enlarged, and the voice becomes low, or grave.

The action of the arytenoid muscle, which extends from one arytenoid cartilage to the other, closes the

glottis by drawing the two cartilages together, and bringing the vocal chords nearer to each other, while the crico-arytenoidei posteriores and laterales, separate the arytenoid cartilages, and widen the aperture of the glottis. The thyro-arytenoid is considered as the most important of the muscles of the larynx, as it forms the lip of the glottis, and embraces the ventricle of the larynx, and is the principal muscle employed in the modulation of the voice. Its office is to draw the arytenoid cartilages outwards and forwards, enlarge the glottis, and shorten and relax the vocal chords. It also compresses the ventricles of the larynx.

The theory of the formation of the voice, according to Magendie, is as follows. The air, forced from the lungs, at first passes into a tube of considerable size; but this tube soon becomes contracted, and the air is obliged to pass through a narrow slit, the sides of which are formed of vibrating plates, which alternately give passage to, and intercept the air, like the reeds of wind instruments; and, by these alternations, produce the sonorous undulations in the current of air, transmitted through the aperture.

The inferior ligaments of the glottis owe their faculty of vibrating, to the contraction of the thyro-arytenoid muscles; and, consequently, without the contraction of these muscles, no voice can be produced. Hence, a paralysis of these muscles occasions a loss of the voice; and, for the same reason, a division of the recurrent nerves, which are distributed to the thyro-arytenoid muscles, destroys the voice.

The superior laryngeal nerves are distributed to the muscles, which close the glottis, and the inferior, to those which dilate it. Hence the division of the latter, or the recurrent, not only occasions a loss of voice, but sometimes produces asphyxia, because the constrictor muscles of the glottis, having no longer any antagonists to their action, contract without opposition, producing a closure of the glottis and suffocation. An aneurism of the arch of the aorta, sometimes leads to the same consequences. The left recurrent nerve, which turns round the arch of the

aorta, is stretched by the aneurismal tumor, and its functions impaired or destroyed; the voice is altered or lost, and suffocation sometimes takes place, even without the rupture of the aneurism.

According to Magendie, an opening in the trachea, below the larynx, destroys the voice, both in man and in other animals: if the aperture be mechanically closed, the voice is restored. Magendie mentions a man who had a fistulous opening in the larynx, and who was unable to speak, unless he wore a tight cravat, which covered the opening. An opening in the larynx, below the inferior ligaments of the glottis, also occasions a loss of voice. On the other hand, a wound above the glottis, even if it injures the epiglottis and its muscles; or an injury of the superior ligaments of the glottis, and even of the superior part of the arytenoid cartilages, does not destroy the voice. Tubercular cavities in the lungs sometimes occasions a loss of voice.

The loudness or intensity of the voice depends on the extent of the vibrations of the vocal chords. This will depend on the quantity of air expelled from the lungs, and the force with which it is driven through the larynx; and upon the length of the vocal chords, or the size of the larynx. A vigorous person, with a capacious chest, and a larynx of large dimensions, has all the conditions favorable to a strong voice. While children, women and eunuchs, in whom the larynx is comparatively small, have, in general, much feebler voices than a healthy man.

Magendie found, upon laying bare the glottis of a dog, by an incision between the thyroid cartilage and the os-hyoides, that when he uttered grave sounds, the ligaments of the glottis vibrated throughout their whole length, and that the air expired, passed out through the whole extent of the slit formed by the lips of the glottis, except at the interval between the arytenoid cartilages, which, he says, are always, during phonation, exactly applied to each other, and suffer no air to pass between them. When the animal uttered acute sounds, on the contrary, the ligaments

vibrated, not in their anterior, but only in their posterior part, and the air passed out only through the corresponding portion of the glottis, and consequently through a smaller opening than in the former case. When the sounds became very acute, the ligaments vibrated only at the extremities nearest the arytenoid cartilages, and the air passed out only at this part of the glottis, which did not exceed two lines in length.

As the principal office of the arytenoid muscle is to close the glottis at its posterior extremity, it must be the principal agent in the production of acute sounds; and, accordingly, Magendie found that the section of the two laryngeal nerves, which supply this muscle, destroyed the power of making acute sounds, and the voice of the animal acquired an unusual gravity. The thyro-arytenoid muscles, Magendie thinks, must exert some influence upon the tones of the voice. The more forcibly these muscles contract, the more their elasticity must be increased, and the more capable they must become of vibrating rapidly, and of producing acute sounds. The less forcibly they contract, on the contrary, the less rapidly they will vibrate, and the graver will be the tones which they produce. The contraction of these muscles, also, probably contributes to close the anterior part of the glottis.

The ventricles of the larynx, immediately above the inferior ligaments, are supposed by Magendie to be designed to isolate these ligaments, so as to allow them to vibrate freely in the air. If foreign substances be introduced into them, or they become filled with mucus, or a false membrane, the voice generally becomes enfeebled, or totally lost.

CHAPTER XXIX.

Generation.

This is a function, by means of which organized living beings reproduce their like, and are thus enabled to perpetuate their species. The modes of generation are very various, though there is a general analogy running through the different modifications of the function, existing in the different forms of organized life.

In all the superior classes of animals a peculiar set of organs exists, to which this important function is assigned. In the lowest orders of animals, as the *infusoria*, the *polypus*, the *hydatids*, and some of the *intestinal worms*, no such organs exist.

In the first case, where organs of generation exist, these, in some animals, are not divided into male and female, and, of course, there is no distinction of sex. Every individual is provided with the organs in question, and no copulation is necessary.

In other animals the organs are of two kinds, male and female, and, of course, a distinction of sex exists; and a union of two individuals is necessary to generation. But here there is a distinction; for, in some cases, each individual is provided with both kinds of organs, male and female, so that a double copulation is effected by a union of two individuals, both of which become impregnated; and in some others, the two sexes exist separately in different individuals, so that some are male and others female; and the union of two individuals of different sexes, by which only the female is impregnated, is necessary to generation.

In some species of animals of the latter kind, one impregnation is sufficient to make several generations fruitful. This is the fact with the *aphides*. In some

others, a single impregnation enables the female to produce young for several times. This is the case with many of the amphibia, and with birds.

Lastly; in the highest class of animals, the mammalia, one impregnation suffices for one birth only.

Organs.

The organs of generation in man and the higher animals, are very complicated, and are divided into male and female.

In the male, the essential part of the apparatus is the testes, and in the female, the ovaries. The testes are glandular bodies, which secrete a prolific fluid, which is necessary to the impregnation of the female. The ovaries are also glandular substances, containing small vesicles, which differ in number in different animals, and in the human species amount, in every female, to sixteen or twenty. These vesicles are considered as the ova, or eggs of the female, containing the rudiments of the future being, but requiring, for their development, the prolific influence of the male fluid.

Male organs.—In adult males of the human species, and many of the mammalia, the testes lie in a sac, called the scrotum; in some others, they always lie concealed in the cavity of the abdomen, as in the *cetacea;* and in some of the mammiferous animals, as hares and rabbits, they change their situation, so that, during copulation, they are lodged in the scrotum, but at all other times, in the abdominal cavity.

The testicles are two glandular organs, of an ovoid figure, a little flattened or compressed, and consisting of blood-vessels and innumerable convoluted, seminiferous ducts, disposed in lobules, which are separated by delicate cellular septa. The seminiferous vessels are so fine, that neither quicksilver, nor any other injection, can be forced from the spermatic artery into these canals, nor backwards from the excretory ducts

of the testes, into the spermatic arteries or veins.* Each lobule contains one of these canals. The number of them is very great, amounting, it is said, to about three hundred, each of which is about sixteen feet long, and the length of the whole, near five thousand feet. Towards the superior part of the testicle, they unite into several larger canals, called the *vasa efferentia*, which anastomose with one another, and, uniting into ten or twelve principal trunks, pierce the *tunica albuginea*, form numerous convolutions, and terminate in the head of the epididymis. This is a sort of appendix of each testis, situated on its upper and posterior part. It is composed of a single convoluted tube, about thirty feet long, the convolutions of which are connected together by cellular tissue. This canal, at the inferior extremity of the epididymis, becomes larger and less convoluted, and turns and ascends behind the testicle into the abdomen, forming part of the spermatic cord, under the name of the *vas deferens*. After entering the abdomen, it separates from the other parts of the spermatic cord, descends into the pelvis by the side of the bladder, to which it adheres, and, converging towards the duct of the opposite side, communicates with the vesicula seminalis, and at length opens into the urethra, near the neck of the bladder.

The vesiculæ seminales are two convoluted tubes, situated, one on each side, near the neck of the bladder, between the bladder and rectum. They communicate freely with the vasa deferentia, and are considered as continuations of these tubes. The vesiculæ seminales are sometimes absent. The testicle is invested with a fibrous membrane, of a whitish color, termed the tunica albuginea, very firm and resisting, yet susceptible of great distension, as certain enlargements and engorgements of this gland sufficiently prove. This coat is designed to protect the organ

* Vid. Berthold. Sœmmering, however, according to Blumenbach, was so successful as to inject all the vessels, composing the testes and the head of the epididymis, with mercury.

from external injuries, and to give it the necessary firmness. Its external surface is covered by the posterior part of the external face of the *tunica vaginalis*, to which it adheres very intimately. This tunic is a process of the peritoneum, and is a serous membrane, investing the testicle, and lining the scrotum.

The testicle is suspended from the abdominal ring, by a bundle of vessels and nerves, called the spermatic cord, formed of the blood-vessels and nerves, &c. which pass to and from the testicle, as the spermatic artery and veins, lymphatics, nerves, and the vas deferens, connected together by cellular tissue. It is covered externally by a fibrous coat.

The bag in which the testicles are contained, is called the scrotum. It is formed by a continuation of the skin of the inner side of the thighs, and of the perineum. It is composed of two symmetrical halves, separated by a raphe. The skin, which forms this sac, is corrugated and contractile. Beneath the outer skin are two reddish vascular membranes, which form two distinct sacs, one for each testicle; and a septum, or partition between them. This tunic, which is termed the *dartos*, is generally considered to be cellular in its texture, though some anatomists have regarded it as muscular. It possesses a strong contractile power. Beneath it is a third tunic, which is evidently muscular, and is called the *cremaster muscle*. It arises from the lesser oblique muscle of the abdomen, passes through the abdominal ring, contributes to the formation of the spermatic cord, and is lost on the inner surface of the scrotum. It draws the testicles upwards.

The *prostate gland* is an organ of a very compact texture, lying between the vesiculæ seminales, and embracing the neck of the bladder. It is considered as a congeries of glandular follicles, which are filled by a viscid, whitish fluid. These follicles have numerous excretory ducts, which open into the urethra. The male organ of generation, or the *penis*, consists of the urethra, surrounded by a spongy body, and of two other spongy substances, which last constitute much

the larger part of the organ. It is a cylindrical body, composed of a vascular and erectile tissue, is provided with several muscles, and is situated at the inferior and anterior part of the abdomen, below and before the *symphysis pubis*.

The canal of the urethra, which runs the whole length of the penis, is situated along its inferior part. It commences at the mouth of the bladder, receives, in its course, the ejaculatory ducts and the excretory canals of the prostate gland. The glands of Cowper, also, open into it, besides mucous follicles. According to Amusat, the urethra is nearly straight when the rectum is empty, and the penis directed forwards and upwards. But when the organ is flaccid, the direction of the urethra is flexuous, having several curvatures.

The urethra is lined with a mucous membrane. That portion of the urethra which forms part of the penis, is supported by a spongy substance, called the *corpus spongiosum*. This is of a cellular structure, inclosed by condensed cellular membrane. The cells, when injected, appear to be composed of a network of arteries and veins. Anteriorly, the urethra swells out into the glans penis, a roundish body, forming the extremity of the organ, and perforated by the orifice of the urethra.

The two other substances which contribute to form the penis, and which constitute about two-thirds of its volume, are the *corpora cavernosa*. These bodies are cellular, like the corpus spongiosum, but the cells are larger, and consist almost wholly of dilated veins. The corpora cavernosa, together with the corpus spongiosum, are surrounded by common integuments, which adhere to them very loosely by cellular substance. At the neck of the glans they become loose and pendulous, forming for the gland a covering, called the prepuce. The corpora cavernosa and the corpus spongiosum, with the glans penis, belong to the erectile tissues.

The testicles derive their blood from the spermatic arteries, which generally spring directly from the abdominal aorta, and are remarkable for their great

length. Upon reaching the testicles, each of them divides into two branches, one destined to the epididymis, the other to the testicle. The spermatic veins arise in the interior of the testicles, by very fine radicles. These veins accompany the ramifications of the arteries, emerge from the testicle by piercing the tunica albuginea, and then unite with the veins of the epididymis. They then ascend along the spermatic cord, anterior to the vas deferens, running in a tortuous direction, and entering the cavity of the abdomen, where those of the right side open into the vena cava, and those on the left into the corresponding renal vein. The spermatic veins, of which there are two or three on each side, are furnished with numerous valves.

The nerves of the testicles are furnished by the great sympathetic.

The penis derives its blood from a branch of the internal pudic artery, which originates in the internal iliac. The veins follow the same course as the arteries. The organ is supplied with nerves by the internal pudic, which derives its origin from the second and third sacral nerves, forming junctions with the great sacro-ischiadic, the trunk of the intercostal, and the splanchnic nerves.

The use of the testes is to secrete a prolific fluid, termed the semen, or male sperm, which is necessary to the impregnation of the female. The principal use of the penis is to project this fluid into the organs of the female.

The semen is a whitish, semi-transparent, albuminous fluid, containing, in a large proportion of water, animal mucus, a peculiar animal matter, sulphur, soda, and phosphat of lime. It has a peculiar characteristic odor, said to bear a strong resemblance to that of the pollen of many plants.

When the semen of a man, or of an adult animal, is viewed through a microscope, an immense number of animalcula, resembling tadpoles in their shape, are seen in it, swimming about with great vivacity. They are observed in the human fluid only after the time of

puberty. They disappear, as it is alleged, during many severe sicknesses, and do not exist in the semen of old men. In dogs, they are present only during the season of their amours; and in hybrids, as the mule, which are incapable of propagation, they do not exist at all. It is remarkable, that these animalcula differ in different species of animals, but are always alike in the same. Their number is so prodigious, that, in a little drop of the spermatic fluid of a cock, hardly exceeding a grain of sand in size, they are said to amount to fifty thousand. By some physiologists they have been considered as the direct agents of impregnation.

The course of the semen, after its secretion from the blood of the spermatic artery in the testicles, is through the tubuli seminiferi to the epididymis, the vas deferens and the vesiculæ seminales, where it is supposed to be deposited, until it is needed during the venereal act. It then passes into the urethra, and is projected, by the male organ, in jets.

The use of the vesiculæ seminales is not known, though, by some, they are supposed to be reservoirs of the semen, as the gall-bladder is of the bile. Whatever may be their use, they are not essential to generation, as many animals are not provided with them.

Female organs.—The sexual organs in females, consist of the *ovaries* and their appendages, with the uterus, and the parts more immediately belonging to it. Or, they may be divided into *organs of secretion*, and *organs of reception;* the first embracing the ovaries and the Fallopian tubes; the second, the uterus, the vagina, and the vulva.

The *ovaria*, which are the essential parts of the female sexual apparatus, are two oval-shaped glandular bodies, about an inch and a half long, and about half an inch in diameter, situated in the abdomen, enveloped by the posterior fold of the broad ligament of the uterus, and each being retained in its place by its proper ligament, called the ligamentum ovarii. They are invested with a peritoneal coat, continuous with

the posterior lamina of the broad ligament of the uterus. The ovaries are composed of a dense cellular substance, containing a number of small vesicles, filled with a limpid, albuminous fluid. These vesicles, which are fifteen or twenty in number, are of various sizes; the larger lying near the surface, the smaller more towards the central parts of the ovaria. The largest of them are about three lines in diameter. They are considered as the unimpregnated eggs of the female, and each is supposed to contain the rudiment of a fetus. The size of these ova is by no means in proportion to that of the animal to which they belong. In the elephant, for example, they are very small. The fluid, contained in them, is analogous to the white of an egg, being coagulable by heat and by alcohol.

The ovaria are connected to the uterus by the broad ligament of the uterus, by the proper ligaments of the ovaria, and by the Fallopian tubes.

The Fallopian tubes are narrow, tortuous canals, which arise from the angles of the fundus uteri, and run in the upper part of the duplicature of the broad ligaments. Their length is from three to five inches. The extremity, which opens into the uterus, is extremely small, being scarcely large enough to admit a hog's bristle. But the tube gradually enlarges towards the ovarian extremity, where it is about four lines in diameter. The Fallopian tubes are composed, each of a layer of longitudinal muscular fibres,* and within this, of another layer of circular ones, lined with a mucous coat, which extends from the corner of the fundus uteri to the ovarian extremity of the tube, where it contributes to form what is called the *corpus fimbriatum*. The ovarian aperture is surrounded by an elegant fringe, derived from the peritoneal covering of the tube and of its mucous membrane, and it opens into the cavity of the abdomen.

The Fallopian tubes are attached, by one of their fimbriæ, to the ovaria.

* Some physiologists deny the muscularity of the Fallopian tubes.

The *uterus* is a hollow organ, situated between the bladder and rectum, and designed for the reception and evolution of the fetus. It is of a pyramidal figure, about two inches long, flattened on its anterior and posterior surfaces, and is divided into a fundus, a body, and a neck. The fundus is the upper part of the organ; the neck or cervix, the inferior part which opens into the vagina; and the intermediate part constitutes the body. The walls of the uterus are very thick, particularly in the body of the organ, where they are nearly half an inch in thickness. The substance of which the uterus consists, is peculiar in its organization, and its real characters are not well ascertained. It is a dense, compact tissue, abounding in blood-vessels, lymphatics, and nerves, and, according to some physiologists, is decidedly muscular. Some anatomists consider the fibres of the uterus as analogous to the yellow fibrous tissue, which exists at the common limits of the cellular and muscular system, approaching the first in the unimpregnated uterus; but assuming all the characters of the second, in the latter stages of utero-gestation. Others regard the tissue of the uterus as condensed cellular tissue. Blumenbach says, that he never yet discovered a true muscular fibre in any human uterus, which he had dissected.

Externally, the uterus is covered with a peritoneal coat. The peritoneum is reflected over the anterior and posterior surfaces and the fundus of the organ; and these two laminæ of the membrane, uniting together at the sides of the uterus, form a broad ligament, which invests the Fallopian tubes and ovaria; and which divides the cavity of the pelvis into two parts. The uterus is also connected with the neighboring parts by other ligaments, as the anterior and posterior, and the round ligaments. Internally, the cavity of the uterus is lined by a mucous membrane. This cavity, which is about large enough to contain an almond, is triangular in its shape, and has three apertures, viz. two at the fundus, which are the orifices of the Fallopian tubes, and the third at the inferior

angle, communicating with the vagina, and called the mouth of the uterus, and sometimes the *os-tincæ*.

Between the mouth of the uterus and the external opening of the organs of generation, is a canal, from four to six inches long, and one or one and a half inches in diameter, termed the *vagina*. It consists of a very vascular cellular tissue, lined with a mucous membrane, presenting numerous semi-circular rugæ. It is somewhat curved in its direction, with its concavity towards the bladder, and its upper part receives the neck of the uterus. The orifice of the vagina is surrounded by a sphincter, called the *constrictor vaginæ*.

Near the external orifice of the vagina is a circular membrane, called the *hymen*, formed by a duplicature of the mucous membrane of the vagina, with an aperture in its centre. It is found only in the human subject, and, for the most part, only in the virgin state. The vagina opens externally by the vulva. This is formed by the *labia pudendi*, two oblong bodies, composed of a duplicature of the common integuments, with adipose matter interposed. They extend from the symphysis pubis to the perineum, meeting at their superior and inferior extremities by commissures, but in their intermediate parts, being separated by a narrow orifice, which is the opening of the vagina.

At the upper commissure of the labia is a small organ, called the *clitoris*, which has some resemblance to the male penis, consisting of corpora cavernosa, capped with a glans, which, however, has no perforation, as the organ is destitute of a urethra. From the clitoris, and within the labia, descend, on each side of the vagina, the *nymphæ* or internal labia. They reach down to the inferior commissure, where they are blended together. The nymphæ are prolongations of the mucous membrane of the vagina, and consist of a delicate spongy tissue, which is continuous with that of the glans clitoridis. About an inch from the glans of the clitoris, within the vagina, under the arch of the pubes, is the orifice of the urethra.

The ovaria receive their blood from the spermatic

arteries, and their nerves from the renal plexus. The uterus is supplied with blood by means of the uterine arteries, which are branches of the internal iliac, and its nerves from the renal and hypogastric plexuses.

Impregnation.—Impregnation is effected by the influence of the male fluid upon the ova of the female; and the functions of a very considerable part of the sexual apparatus in both sexes, are subservient to the object of effecting the approximation of these two essential elements of generation. To the accomplishment of this object, the intromission of the male organ into the female vagina, and an ejaculation of the prolific fluid into the interior of the sexual organs of the female, are necessary.

To adapt it to this function, the penis, which is composed of an erectile tissue, has the power, when under the influence of sexual desire, of becoming rigid and swollen from a congestion of blood in its corpora cavernosa, the urethra and glans. Artificial erection may be produced after death, by injecting the organ. The congestion is evidently of an active kind, as appears from the increased throbbing of the arteries of the part. The blood is solicited into the organ by the peculiar irritation which affects it at the time, and is accumulated in the venous plexuses, of which the erectile tissue of the organ consists. Cuvier was of opinion, that the veins are chiefly concerned in the production of erection, because they predominate so much in the structure of the corpora cavernosa, and because the nerves, which are the conductors of the mental stimulus, terminate chiefly in the veins. Perhaps both the arteries and the venous plexuses are concerned in the effect.

The erection of the penis bestows on the organ the necessary degree of firmness, to effect the penetration of the external organs of the female. But the ejection of the male fluid, during the introduction of the penis, is also necessary. The irritation, which gives rise to the erection of the penis, continues during the venereal act, and extends to the rest of the genital apparatus. Under the influence of it, the testes secrete the male

fluid more copiously, which passes through the excretory canals of the two glands, into the vesicula seminales. These reservoirs partake in the excitation, contract forcibly, and project the spermatic fluid into the urethra, which canal becomes excited to the highest degree of orgasm by the contact of the fluid. The excitement extends to the ischio and bulbo-cavernosus muscles, the transversus perinei, and the levator ani. The first of these muscles keeps the organ erect, and in a proper direction for its introduction into the vagina; and they all concur in projecting the fluid along the urethra. By the agency of these powers, the semen is ejected from the urethra, in jets, into the vagina of the female. With the seminal liquor are ejaculated the fluids, secreted by the prostate gland and the glands of Cowper.

According to some physiologists, the seminal fluid is accumulated in the bulb of the urethra, previous to its emission. The bulbous part of the urethra seems to be well fitted for the purpose, and the muscular contraction, by which the emission of the fluid is effected, first acts upon this portion of the canal.

During the venereal act, the female, as well as the male organs are in a state of erection. The clitoris and the erectile tissue, which lines the interior of the vulva and the vagina, are in a state of turgescence, and a considerable secretion of mucus takes place from the surface of the vagina.

The completion of the act is succeeded, on the part of the male, by a cessation of the local erethism, with a return of the penis to its ordinary state of flaccidity, and a feeling of languor and weakness. A similar state of feeling occurs in the female, though in a less degree.

It has been a disputed question with physiologists, to what point in the female organs the male fluid is projected, and where it exerts its fecundating power. Different opinions have been entertained on this question. According to some physiologists, the seminal fluid gets no further than the superior part of the vagina; and they suppose, that fecundation is accom-

plished, either by the absorption of the semen by the vessels of the vagina, whence it reaches the ovaria, in the course of the circulation; or, by means of some subtle emanation, disengaged from it and conveyed to these organs. In proof of this opinion it is alleged that, on opening female animals immediately after copulation, no semen can be discovered in the uterus. The extreme narrowness of the Fallopian tubes, furnishes another argument in favor of this opinion.

Others suppose, that the spermatic fluid is projected into the uterus, but no farther; that the female organs furnish another material, which also is conveyed into the uterus, and that impregnation results from the mixture of the two.

According to a third opinion, a portion of the male fluid is conveyed, by a peculiar action of the Fallopian tubes, to the ovaria, where fecundation is accomplished.

The last opinion is regarded as most probable, at least, with respect to the human species. No doubt can exist, that fecundation takes place in the ovaria, and that the influence of the male fluid must, in some mode or other, be conveyed thither. The development of the fetus in the Fallopian tubes, in the ovaries themselves, and even in the abdomen, probably from an escape of the impregnated ovum out of the ovarian extremity of the Fallopian tubes, furnish strong evidence of the truth of this opinion. Nuck once effected a pregnancy of the Fallopian tube in a bitch, by applying a ligature, three days after copulation, to one of the horns of the uterus. It is true, that, in some animals, as fishes, the ova are not fecundated until they have been evacuated from the body, and, of course, in these animals at least, impregnation certainly does not take place in the ovaria.

It appears to be ascertained, that the seminal fluid does, in fact, reach the uterus. Some physiologists, it is true, could never discover it in this organ after copulation. But others have been more successful. Thus, Haller found it in a sheep; Ruysh, in the uterus of a female, who was caught in the act of adultery by

her husband; and M. M. Dumas and Prevost, even in the Fallopian tube. These last-mentioned physiologists admit, that they have seen it even in the Fallopian tubes. It appears to be necessary that there should be actual contact of the spermatic fluid with the ova, to effect impregnation. Thus, in an experiment of Spallanzani, ten or twelve grains of semen were put into a watch-glass, and twenty ova into another, which was placed over the former, but, in such a manner, that no contact took place between their contents. After some hours, the seminal fluid was evaporated to such a degree, that the ova were moistened by the vapor, but still they were not fecundated by it. But fecundation was produced, by the residue of the semen, as soon as the ova were placed in contact.

Dumas and Prevost made an experiment of a still more conclusive kind. They prepared fifty grains of a prolific liquor, with the fluid expressed from twelve testicles, and as many vesiculæ seminales. With ten grains of this, they fecundated more than two hundred eggs. The remaining forty grains were then put into a small retort, with an adopter fitted to it. In the adopter were placed forty eggs. The apparatus was then placed under a pneumatic receiver, and the air exhausted, until one half of the atmospheric pressure was removed. The retort was afterwards exposed to the rays of the sun, in order to raise its temperature. After four hours, some of the eggs were found bathed in a clear liquid, which was the product of the distillation, and swollen, but without presenting any appearance of development. Those of the eggs, which were placed near the back of the retort, had undergone no change. Impregnation, however, was afterwards effected by plunging the eggs in the liquor which remained. It appears, therefore, that the volatile part of the spermatic fluid, which is raised by distillation, has no prolific power; while the fixed part, which remains, retains this power unimpaired.

It must, therefore, be concluded, that actual contact between the seminal liquor and the ova, is necessary

to impregnation, and that the former must be conveyed from the uterus to the ovaria by the Fallopian tubes.

It is probable that, during the orgasm of copulation, the Fallopian tubes partake in the erection, which affects the sexual organs, and apply their pavilion, or ovarian extremity, to the ovaria, and convey thither a portion of the spermatic fluid. The extreme narrowness of the Fallopian tubes at their uterine extremity, affords no solid objection to this opinion; for, we know that, at a later period, these canals admit of the passage of the impregnated ovum into the uterus; and besides, it must be considered that an exceedingly minute portion of the seminal fluid is sufficient for impregnation. It is also known that, in plants, the pollen of the stamina must traverse the vessels of the style, in order to produce fructification; and these canals are, undoubtedly, much narrower than the Fallopian tubes in animals.

From numerous observations, made by different physiologists, it appears that the spermatic fluid, after passing from the uterus through the Fallopian tubes, comes into contact with one or more of the vesicles of the ovaria; that the vesicles which have been exposed to this contact, at first swell, and afterwards burst their envelope, and permit the escape of a minute body, which has generally been considered as an ovum, which is conveyed into the uterus by the Fallopian tube, and becomes the rudiments of the future fetus. The *debris*, or the pericarp of the ovule, remains in the ovaria, under the name of the *corpus luteum*. It appears, from these facts, that the Fallopian tubes execute a double office, viz. that of conveying the seminal fluid from the uterus to the ovaria, and afterwards that of bringing an impregnated ovum from the ovaria to the uterus. In proof of these facts it appears, that, during the spasm of copulation, the pavilion of the Fallopian tube always closely embraces the ovaria. De Graaf, in his experiments, found it thus adhering, twenty-seven hours after copulation. This close grasping of the ovaria, by the pavilion of

the Fallopian tube, is very intelligible, if we suppose its object to be, to convey something to and from the ovaria. Magendie, in one instance, actually saw the extremity of the Fallopian tube applied to a single vesicle. Abdominal and tubular pregnancy are an evidence to the same effect. If the pavilion suffers the ovum it has embraced to escape, the latter falls into the abdomen, and abdominal pregnancy is the consequence. If, by any cause, the ovum is arrested in its passage through the tube, tubular pregnancy is the result.

Haighton found, that, when he divided the Fallopian tube on one side, in rabbits, impregnation took place only on the uninjured side. When he made this section after copulation, he found that it prevented the passage of the ova into the uterus, if the operation was performed forty-eight hours after the sexual act; but if delayed for sixty hours, it failed of producing this effect. A surgeon, named Bussieres, once had the rare opportunity of seeing an ovum partly adherent to the ovary, and partly detached, and engaged in the Fallopian tube.

It is very doubtful, what kind of action these tubes exert in conveying the ovum to the uterus. Some physiologists contend, that they are muscular, and contract like other muscular canals; but, it is more probable, that they exert an erectile action, the consequence of the spasm, into which the organs of generation are thrown during the venereal act.

It is a well-known fact, that hen-birds, which have not been impregnated by the male, sometimes lay eggs, which, however, are unfruitful; and a similar fact seems to be ascertained with respect to viviparous animals. Buffon asserted the existence of *corpora lutea* previous to impregnation; and Cruikshanks says, that he had seen them in the ovaries of virgin rabbits. Sir E. Home declares, that he had seen corpora lutea in the ovaria of women who had died virgins; and he asserts that, in the females of quadrupeds, in heat, and in women at indeterminate periods, the ovaries suddenly become vascular, and ova escape

from them and pass through the Fallopian tubes, which are then in a state of turgescence, or erection, with their pavilion closely embracing the ovaries, to the uterus. These phenomena recur whenever the animal is in heat, and in women at any time, until the critical period of life. It seems, therefore, that the females of viviparous animals, as well as birds, continually part with unfruitful ova, and that fecundation depends on the concurrence of copulation with the presence of mature vesicles.

On the whole, it seems to be ascertained that corpora lutea may exist independently of sexual intercourse, merely from high venereal excitement; and under the same circumstances, it is probable that a vesicle sometimes bursts its envelope, leaving a corpus luteum behind, and escapes from the ovary, passes along the Fallopian tubes, which then closely embrace the ovaria, and enters the uterus; but, being unimpregnated, undergoes no further development, and may be discharged in the same manner as the unimpregnated eggs of oviparous animals.

Theories of Generation.

Of the intimate and essential nature of the process of generation we are wholly ignorant. Innumerable hypotheses have been formed on the subject, but no satisfactory theory has yet been framed; and, considering the nature of the subject, none, perhaps, is to be expected. Some of the most prominent opinions which have been presented to the world, by ancient and modern physiologists, will here be noticed.

The theories of generation have differed according to the ideas which physiologists have entertained of the nature of the spermatic fluid, and of that of the matter furnished by the ovaria of the female.

The seminal liquor by some physiologists has been considered as a fluid composed of the elements of each of the different parts of the human body, and as destined to reproduce every one of these parts in the formation of the embryo; by others as a vehicle, con-

taining animalcules, some of which, after undergoing several metamorphoses, are destined to be elevated to the rank of the beings by which they were produced; by a third class, as a vivifying principle, designed to impress upon the germ the first movements of life and development.

In regard to the matter furnished by the ovaries, the same differences of opinion exist. According to some, it is a vesicle filled with a spermatic fluid, formed, like that of the male, out of the elements of every individual part of the body: or, it is a vesicle destined to serve as a nidus to the spermatic animalcule, or to furnish it with nutritive matter. Some regard it as an amorphous substance, possessing a gelatinous nature, which renders it fit to receive the principle of life, and of organic development; others consider it as a germ, a prëexisting ovum, in the female, having the aptitude to form, under the prolific influence of the male fluid, an individual similar to that which furnished it.

The numerous theories which have been formed from these assumptions, have been usually classed under two general heads, the theory of *epigenesis*, and that of *evolution*.

I. *Epigenesis.*—The theory of epigenesis implies, that the new individual is wholly formed out of molecules of matter, furnished by the two sexes. A peculiar unknown power, differing from the general forces of matter, presides over the union of these molecules, and their organization into the new individual, and bestows upon the latter all its properties. Physiologists, however, have differed much in the mode in which they have conceived of the doctrine of epigenesis, and the application which they have made of this system.

According to Hippocrates, each sex has its own semen, a fluid formed out of materials derived from all parts of the body, and especially the nervous parts. In generation these two fluids are mixed in the uterus, and, by the influence of the heat of this organ, form, by a kind of animal crystalization, the new individual.

According to Hippocrates, each semen, that of the father and that of the mother, is composed of two parts, one strong, the other weak; the union of the two feeble parts produces a female, that of the two strong parts, a male. The child resembles the father or the mother, according to the predominance of the male or female semen.

According to Aristotle, the female does not contribute a seminal fluid in generation, but the menstrual blood. This forms the basis of the new individual; and it is the male fluid which gives it form, and impresses upon it a vital movement.

The doctrine of Hippocrates, in a modified form, has been adopted by various modern physiologists. Descartes attributed the formation of the new individual to a fermentation of the two seminal fluids of the male and female; Pascal, to a chemical combination of the male semen, which he supposed to be acid, with that of the female, which was considered to be alkaline.

The celebrated naturalist, Buffon, revived the old doctrine of Hippocrates in a modified form. According to Buffon, there exist in nature two kinds of matter, one living, the other dead. The first consists of an infinite number of minute, incorruptible particles, which Buffon calls organic molecules. These molecules, in combining in greater or less numbers with dead matter, form all organized bodies; and, without ever being destroyed, they pass incessantly from plants to animals, by nutrition, and return from animals to plants, by death and putrefaction.

These molecules, according to Buffon, compose the chyle, and the aliments out of which the chyle is formed. They are employed in forming all the organs of the body, in their nutrition and growth. If they are too abundant in certain parts of a living body, they may give rise to spontaneous productions and parasitic animals, as hydatids, worms, and insects. Oftentimes they unite together and become organized, out of living bodies; and then they form true organized beings, without sexual generation. As long as a living

being continues to grow, all the organic molecules are employed in its nourishment and development. But when it has attained its full growth, while it is still young, and full of life and vigor, these molecules, being too abundant for the ordinary wants of the individual, accumulate in the testicles and the seminal vesicles of the male, and in the ovaries of the female; and in the anthers and the receptacle of plants; and the result is, the formation of the pollen of plants, the spermatic fluid of male animals, and the corpora lutea of the ovaries in females, and the *cicatricula* of eggs in oviparous females.

As these organic molecules, always active and always living, circulate equally in all parts of the body, all the organs and humors are impregnated with them; and as soon as they exceed the quantity required by the wants of the organs or fluids, the excess is immediately conveyed from each part to the common reservoir, where they are collected together. Of course, the male semen contains organic molecules from all parts of the body of the male; whence it is easy to conceive that the new animal, formed from this semen, must resemble its father. In like manner, the corpora lutea of the female ovaria are composed of organic molecules of every organ of the female, and, in fact, contain a kind of *extract* of the whole body of the female; and consequently, the new animal, formed out of the combination of the corpus luteum of the female and the semen of the male, ought to resemble, at the same time, both its parents. The molecules of similar parts, in the two sexes, unite together. Those, for example, which come from the eye of the father, combine with those derived from the eye of the mother, and so of all the other organs. The sex of the fetus will be determined by the predominance of the male or female semen in the mixed fluid, which produces the young. A similar cause will determine its greater resemblance to one of its parents than to the other. Buffon also supposed that every plant and animal forms a mould, in which organic molecules are collected together, and become organized.

This whole system of generation, it will be perceived, is mostly a tissue of ingenious hypothesis, wholly destitute of proof. The organic molecules, the moulds, formed by different animals and plants, the vesicles of the ovaria being filled with semen, this semen being an extract of all the organs and fluids of the body;—all these are mere assumptions, wholly destitute of evidence, and even of probability.

II. *Evolution.*—This system supposes that the new individual prëexists, in some form or other, in one of the sexes, that it is animated by the influence of the other sex in generation, and then begins a series of developments, the result of which is to form an independent being. The partizans of this system are divided into two sects, viz. the *ovarists*, and the *animalculists*.

The ovarists ascribe the principal share in generation to the female; and they assert, that the part contributed by the female is an egg, which they define to be an organized substance, formed of an embryo, and of particular organs, destined to subserve the nutrition and the first developments of the embryo, and fitted to become, after a series of these developments, an individual similar to that from which it sprung. This system was derived from observation of oviparous animals, in which the female furnishes an egg, and in many of which this egg is laid before copulation, and is fecundated out of the body. This disposition was extended, by analogy, to oviparous animals, and hence the celebrated saying of Harvey, *omne vivum ex ovo*.

This theory was supported by many considerations, among which are the following:—1. The prëexistence of the germ, before fecundation, in many organized beings. In plants, for example, the rudiments of the seed exist in the flower before the pollen, destined to fecundate it, has arrived at maturity. In birds, eggs exist in the female before copulation, and are sometimes laid by virgin birds. In fishes and some of the reptiles, the egg is not fecundated until it has been excreted from the body; and Spallanzani affirms, that he has seen the rudiments of the tadpole in the unim-

pregnated eggs of the frog; and Haller says the same with regard to the hen's egg.

2. Another consideration is the curious fact, that, in some species of animals, a single copulation is sufficient to give fecundity to many successive generations. Now, in order that several generations should thus be fecundated by a single copulation, it seems to be necessary that the germs, from which they are derived, should prëexist in the first.

3. Another fact, in favor of the same view, is the involution of germs in many plants and animals. Thus, the bulb of the hyacinth contains, ready formed, the rudiments of the flower which is destined to spring from it. In the buds of trees, also, may be seen, folded up, extremely minute branches, leaves, and even flowers. In the jaws of certain animals, the germs of several series of teeth are visible. In the volvox, a transparent animal may be seen, several young inclosed in one another, like a nest of boxes; sometimes an egg is found inclosed in another, and fetuses have been discovered, in several instances, contained in the human body.

4. Further; in frogs and insects, animals which undergo a striking metamorphosis, it is observed that the forms which they successively assume are evidently contained in those which precede them. The young frog may already be discovered under the skin of the tadpole; the lineaments of the future butterfly are distinguishable in the crysalis, and those of the crysalis in the caterpillar. The minute quantity of semen which is sufficient for impregnation, furnishes another reason for believing that this fluid can contribute nothing more than a vivifying influence to the materials furnished by the female.

Several objections have been made to the theory of the ovarists. 1. One is, the resemblance of the young to the father. This resemblance is sometimes so great, that it seems to contradict the idea of a prëexisting germ in the ovum. For example, men with six fingers on a hand, frequently beget children distinguished by the same peculiarity; and many other peculiarities of

the father may, in the same manner, be transmitted to the child.

2. The existence of hybrid plants and animals, proves the great influence exerted by the father upon the qualities of the fetus. The child of a black father by a white mother, has a color intermediate between the complexions of his two parents; and if the successive generations of the offspring of a white woman be united to negroes, they will, at last, lose all trace of the primitive color of their race, and become perfect negroes.

3. It has also been objected to the theory of prëexisting eggs, that the lapse of time is incessantly producing changes in the species of plants and animals, which live at the surface of the earth. Linneus was of opinion, that there existed, in his day, more plants than in ancient times, and of course that new species of vegetables were formed. Lamarck supposes, that all plants and animals are continually changing by the influence of climate, season, domestication, and the crossing of breeds; and the reason that the existing species appear permanent is, that the circumstances which modify them require an enormous time to act, and the life of one man is too short to enable him to witness these changes. This opinion of Lamarck is in harmony with that which he has broached relative to the origin of organized beings; the vital movement, as he supposes, always having the effect of making the organization more and more complicated, and, consequently, producing incessant changes of species.

The ovarists are divided into three classes. One class supposes that the ova, or germs, are disseminated throughout space, and only develop themselves when they penetrate into bodies capable of retaining them, and causing them to grow; i. e. beings similar to themselves. This is called the system of *pansperm*y, or *the dissemination of germs.* A second class hold, that the ova are inclosed in one another, in a series, and developed, one after another, by successive generation; so that not only the ovaria of the first female contained the ova of all her own offspring, but

a single one of these ova contained the whole human race. This is the celebrated system of the *involution of germs.* A third class of ovarists maintain that every female forms her own ova, by a kind of secretion.

The other sect of the advocates of the system of evolution are called *animalculists;* a name derived from the minute animalcula existing in the male semen. In 1674, Ham, and Lewenhoeck, and Hartsæker, discovered in the semen of animals a prodigious number of small bodies, which, from their motions, they inferred to be animals; a discovery which gave rise to a new system of generation, viz. that of spermatic animalcula. It was supposed that these minute animals, after undergoing a series of metamorphoses and developments, were, at length, formed into new individuals. As in the system of the involution of germs, the first woman is supposed to have contained the whole human race, in this system it is the first man that contained all succeeding generations, the spermatic animalcule being the prëexisting germ, the organized homunculus, in which the whole future race was inclosed.

It appears, that spermatic animalcules exist in the semen of all animals, and that they are not found in any other animal fluid. It also appears, that they differ in different species of animals, but in the same species are always alike. They exist in the semen only during the age when generation is possible, and are absent both in the first and last periods of life. Their number is so great, that a drop of the seminal fluid of the cock, not larger than a grain of sand, contains no less than fifty thousand. The extreme minuteness of these animalcula affords one means of explaining the fact, that Spallanzani was able to effect artificial fecundation with very minute quantities of seminal fluid.

Assuming, then, that spermatic animalcula are the rudiments of the new individuals, Lewenhoeck says, that, when projected into the uterus, they attract the ova, and convert them into real embryos. Andry

supposes that they crawl through the Fallopian tubes, reach the vesicles of the ovaria, in one of which a single animalcule incloses itself, then returns with it to the uterus, and begins to develop itself, by means of the nutritive matter contained in the ovum. Spallanzani regarded these animalcules as analogous to the infusory animalcula; and Buffon considered them as his organic molecules.

More recently, Dumas and Prevost have recalled the attention of physiologists to these minute animals. They not only assert their existence, but they consider them as the direct agents of fecundation, and as bestowing upon the semen its aptitude for this office. By the aid of the microscope, they discovered them in the semen of all the animals which they examined, the number of which was very great. They were discovered, not only in the semen just excreted by living animals, but also in the fluid taken, after death, from the vas deferens and from the parenchyma of the testicles. But they were not found in any other fluid of the body, not even in the other humors secreted by the sexual organs, as the liquor of the prostate gland, that of the glands of Cowper, &c. In animals of the same species, these animalcula were observed to resemble one another in shape, size, and motion; but in those of different species they were alike in these respects. They executed spontaneous motions, which, in the semen obtained during life, by ejaculation, gradually ceased in two or three hours; but in that which was taken from the spermatic vessels after death, continued only fifteen or twenty minutes; but if the semen was left in its proper vessels after death, the motions continued eighteen or twenty hours. These animalcules exist in the spermatic fluid only when generation is possible. In birds, with the exception of the cock and pigeon, they are found in the semen only at the season fixed by nature for copulation in these animals. Another curious fact is, that they appear to be influenced by the physiological state of the animal which furnishes them. Their motions are rapid and brisk, or languid and slow, according as the animal is young

or old, in a state of health or disease. In their researches upon the ova of the mammalia, Dumas and Prevost observed the animalcules filling the cornua of the uterus, and remaining there, alive and in motion, until the descent of ovula into these organs, after which they gradually disappeared. The seminal fluid loses its prolific power in about twenty hours, and in the same interval of time, the animalcules contained in it gradually cease their motions and perish. If the semen be evaporated to dryness, and afterwards diluted with water, it loses its fecundating power. Dumas and Prevost found also that when the animalcula were killed by repeated electric shocks sent through a liquor impregnated with semen, this liquor lost its prolific powers.* In another experiment, having separated the animalcula by filtration, the liquor which passed through was found to be incapable of effecting fecundation, while that which remained on the filter retained this power. Spallanzani had before obtained the same result with the water with which the filter was washed. From these facts, Dumas and Prevost infer that the spermatic animalcules are the immediate agents of fecundation; and, they conjecture, that the animalcule forms the nervous system of the new individual, while the ovum furnishes only the cellular matrix, in which the organs are formed.

Perhaps all that can be logically concluded from the researches of Dumas and Prevost is, the existence of animalcules in the spermatic fluid, and the active part which they take in fecundation.

Bourdon is disposed to adopt the system of the prëexistence of germs in the ova of the female; and, he observes, that the new being appears first inclosed in the ovum, when detached from the ovaria of the mother. And, since it is surrounded, from its first appearance, with several membranes, it seems probable

* Spallanzani, however, according to Bourdon, took some of the semen of reptiles, carefully destroyed the animalcules in it, and yet fecundated the ova which he moistened with it. And Bourdon affirms, that semen, deprived of all its visible animalcula, still enjoys the power of fecundating the ova of the female.

that the ovum contained originally, if not the fetus, wholly formed, at least the rudiments of the embryo and its organs. The first lineaments of the new animal are already indicated, by a white spot in the unimpregnated egg of birds; and these first traces of organization are still more evident in the ova of some of the reptiles. That the germ is not visible in every ovum, is no proof that it does not exist, because every organ exists first in a fluid state, and every fluid which is perfectly transparent is invisible. In proof of this, it is worthy of remark, that the organs which first manifest themselves, have, from their first appearance, a considerable volume; a fact which makes it probable that they existed in another state before they became visible; and that, instead of being formed by degrees, and spontaneously, they had only undergone a kind of metamorphosis.

But if the germs, although invisible, really prëexist in the ova of the female, it seems to follow that these first germs must contain new ones; and, in fact, that all the individuals of the same species must be contained in the ova of the first female of this species; in other words, the prëexistence of germs in the ova of the female, seems unavoidably to infer the indefinite involution of germs. This supposition is beset with difficulties, which appear insurmountable; but, Bourdon thinks that the doctrine may be conceived of in a manner which will elude them, or destroy their force.

Every germ, he says, contains all the elements of the organs of the new animal; but, it contains them only in a latent state, in the state of primitive elements, not yet characterized and manifest. Under the form of a transparent fluid, whose parts are invisible, there exist the principles, by means of which the whole future animal is to be formed and organized; and, since the principles or rudiments of all the organs exist in this colorless fluid, the lineaments of the ovaries must be present there likewise, as well as the elements of all the other organs; and as these ovaries contain new ova, and these ova, in their turn, contain the pre-

formed elements of the future embryos, it is apparent that all these organs contain, in their turn, and simultaneously, the lineaments or rudiments of the beings which are successively to appear; since each germ contains all that is necessary to constitute a new being, and, of course, the rudiments of the ovaries, as well as of all the other organs. In short, every ovum contains a germ; every germ is composed of the elements of a new being; and the ovaries are represented in this assemblage, as well as all the other organs. Now, every ovary contains numerous ova, each one of which contains the rudiments of new ovaries, new ova, and new germs. This theory, therefore, only supposes the existence of a first germ, containing all the principles necessary to the formation and perfect organization of a single embryo. All the rest of the system flows naturally from this one principle.

Many objections, it is true, have been made to this theory. It has been asked, whether it be possible to conceive of this infinite series of bodies, inclosed one in another, from the time of the creation until the final extinction of the species. But this, according to Bourdon, is too gross and material a view of the subject. These germs in each species, he considers, not as consisting of material elements, but merely as an aptitude or predisposition to engender them. The supposition that every new being has its primitive source in the ova of the female, is by no means inconsistent with the admission, that the male fluid must influence the germ, and of course is not at variance with the fact of the resemblance of children to their fathers.

Another objection is founded on the successive appearance of the organs, their changes of form, their complications, &c. For, if the organs appear successively, if they change, become more complicated or more simple, they cannot have a contemporaneous origin, and their elements cannot have been preformed. In support of this argument it is alleged, that the heart of the mammalia and birds, at first have only a single ventricle and a single auricle, and

that they acquire successively the parts which are wanting when they at first appear. It is also alleged that the organs are at first divided, or are formed in pieces, and that the materials of them are more numerous than they appear in the organ when completed.

On the whole, the objections to the doctrine of the prëexistence of germs are so strong, that most physiologists of the present day have adopted the theory of epigenesis, according to which, the seminal fluid of the male is united to a material furnished by the ovarium of the female, and the embryo is formed by the union of the two; and both of the material elements of generation, furnished by the two sexes, are the result of a secretion from the ovarium in the female, and from the testicles in the male.

The history of conception, of utero-gestation, and of fetal life, though belonging to the subject of physiology, are omitted in this work, as they are usually considered in treatises on obstetrics.

CHAPTER XXX.

Sleep.

Sleep is a periodical suspension of the animal functions, during which, the individual is deprived of his consciousness, of his sensibility to impressions made upon his organs of sense, and of his power of voluntary muscular action.

The animal functions, viz. those of sense, of voluntary motion, and of the voice, together with all those functions of the brain, in which the consciousness or

the will are concerned, as perception, judgment, memory, &c. are strikingly distinguished from the other functions by the remarkable circumstance, that they cannot be kept in uninterrupted action beyond a certain period of a few hours' duration; after which, a peculiar sensation, termed fatigue or lassitude, irresistibly compels us to suspend their exercise, a torpor or oblivion steals over the senses, wraps them up as in a mantle, from surrounding objects, and, at length, reaching the brain, involves the centre of animal life in unconsciousness, and wholly isolates the individual from the external world.

The approach of sleep is announced by an internal sensation, termed drowsiness, which gradually increases in strength, and, at length, becomes irresistible. It is accompanied by frequent yawnings, languor of the muscles, heaviness of the eyes, and inclination to close them, difficulty of supporting an erect or sitting posture, and a strong inclination to lie down. The head inclines towards the chest, or sinks upon one shoulder; the external senses become torpid, and the powers of sensation gradually retreat inwards, to the brain, leaving the organs with which they are connected, insensible to external impressions. The voice and speech are also affected with the same torpor. The voice becomes feeble, the articulation is confused, indistinct and unintelligible, and, at length, ceases. The muscles of respiration, and the orbicular muscles of the eye-lids, form the only exception to the cessation of voluntary muscular action. Respiration is still carried on, though, in perfect sleep, chiefly by the diaphragm; and the orbicular muscles contract at the approach of sleep, to close the eyes against the impression of light.

The functions of the brain, also, are suspended in sleep. A kind of delirium seizes upon the mind, in which, objects and images float confusedly through it, which are partly the result of external impressions imperfectly perceived, and exciting an imperfect reaction in the brain. The internal sensations, as hunger, thirst, pain, &c. cease to be felt, and the

intellectual and moral operations are suspended; consciousness is for a time abolished, and sleep at length is fully established.

During this suspension of the animal functions, the nutritive, or organic, continue without interruption; and, according to some physiologists, even with greater activity than during the waking hours. This, however, is not the fact. Respiration is slower and deeper, and sometimes noisy; the pulsations of the heart and arteries are also less frequent, though the pulse is fuller; the temperature falls—a circumstance which is partly owing to the diminished frequency of respiration; the cutaneous transpiration is increased, and the urine is secreted less abundantly in the same proportion; the urine also becomes more concentrated, and loaded with saline matter, from the absorption of its aqueous parts. Hence, the formation of calculus of the bladder is apparently promoted, by habits of great indulgence in sleep.

The duration of sleep varies with numerous circumstances, from a few minutes to several hours. The average duration of the regular periodical sleep, in adults, is from five to eight hours. Infants require much more. The quantity of sleep required by different persons depends much on the power of habit. Men engaged in active and anxious pursuits, requiring all the time they can possibly afford, frequently acquire the habit of sleeping very little. Blanc states, that he was informed by the celebrated general Pichegru, that, in the course of his active campaigns, he had, for a whole year, not more than one hour of sleep, on an average, in twenty-four hours.* The same writer mentions another curious fact on this subject, which he learned from a gentleman who had long resided in China. The missionaries in that country, wishing to devote as much of their time as possible to their duties, used the following means to abridge the period of their sleep. They threw themselves on a couch, with a brass ball in the hand, under which

* Elements of Med. Logic.

was a brass basin. The moment they dropped asleep, the ball fell from their hand into the basin, and the sound waked them. This momentary sleep, they found, afforded all the refreshment which nature required. Alexander the Great, it appears from Q. Curtius, sometimes adopted a similar method to reduce the period of his sleep to the smallest possible allowance. The explanation of the fact, that, in many cases, so little sleep is sufficient to afford the necessary refreshment, is to be found in the circumstance, that the first part of sleep is the most restorative. After sleep has continued a sufficient time, and is approaching to its close, some of the animal functions begin to act again, or at least are disposed to do so, on the application of the slightest excitation. Indeed, in sleep, the animal functions are not all plunged in the same degree of torpor, or, at least, they do not all require the same quantity of repose to recover their aptitude to act. Those which require the least, and which, of course, are most easily excitable, are the intellectual faculties, as appears by the frequency of dreams, which may be excited during sleep by any irritation, external or internal. Next to the mental faculties, the senses of touch and hearing are most excitable, as appears from the changes of posture which so frequently take place during sleep, and which are probably owing to some uncomfortable sensation, produced by impressions on the surface of the body, and from the fact that a loud noise frequently rouses a person from sleep. The sense of sight, and the voluntary muscular actions, are those which are roused from sleep with the greatest difficulty.*

The remote *causes* of sleep are various, but they may all be reduced to the following heads, viz.—

1. The exhaustion occasioned by the impressions constantly made upon the senses by external objects, and the reaction of the cerebral and voluntary powers, produced by these impressions; or, in the language of some of the German physiologists, fatigue and ex-

* Dict. de Medicine.

haustion, produced by the conflict between the macrocosm and the microcosm.

2. The diminution or abstraction of the excitations habitually applied to the system, by which the animal functions are maintained in a state of activity.

3. Increased activity of other organs, or a concentration of vitality in them, producing a derivation of vital power from the same.

4. Certain pathological states of the brain, causing a diminished nervous energy, constitute another class of causes; as, for example, mechanical compression, or congestion of the brain, the use of narcotics, particularly opium, &c. alcohol, &c.

To the first class belong protracted watchfulness, long continued bodily or mental exertion, especially the latter; because the operations of the intellect and of the senses are the highest manifestations of life; violent pain, and exhaustion, from any cause.

To the second, the abstraction of light and sound, and certain uniform monotonous impressions made upon the organs of sight and hearing, as the murmuring of the winds, the buzzing of bees, the noise of a distant waterfall, the ticking of a watch, the dull monotony of a prosing speaker, and the sudden cessation of such sounds.

To the third class belongs *digestion*, which is frequently accompanied with sleepiness, because the powers of the system are then concentrated in the stomach. The somnolency which frequently accompanies fevers, inflammations, &c. and some other diseases, may be referred to the same head, and the greater proportion of sleep required by children and by females during utero-gestation; since, in these cases, production and nutrition are maintained in a state of great activity, at the expense of the higher manifestations of life.

The fourth class needs no illustration.

The efficient cause of sleep is unknown. Blumenbach supposes it to be a diminished flow of arterial blood to the brain, since this fluid is the great excitant of the brain, and is necessary to maintain the reaction

of this organ upon the senses and the voluntary muscles. The influx of blood is diminished by its derivation from the brain, and its congestion in other parts; and it is impeded by pressure upon the brain, occasioned by foreign substances, as serous or purulent effusion or depression of a piece of the cranium. It is not very clear, however, in what mode the exercise of the sensorial and voluntary powers, the usual causes of sleep, can induce a diminution of the quantity of arterial blood in the brain. Indeed, causes which increase as well as those which diminish the quantity of blood in the brain, may induce sleep. Hemorrhage may bring on sleep, perhaps by depriving the brain of the necessary quantity of blood; but the same effect may also be produced by obstructing the return of blood from the brain, or by increasing the influx of blood into the organ, as by the use of strong drinks, which occasion a fullness of its vessels.

Haller, and several other physiologists, have supposed, that sleep depends on an accumulation of blood or other fluids in the vessels of the head, causing pressure upon the brain, and impeding its functions; an opinion deduced partly from the effects which pressure upon the brain, from congestion of blood or other causes, actually produces. It does not appear, however, in what manner the usual causes of sleep can produce an accumulation of blood in the brain; and besides, we ought not to confound natural, healthy sleep, with a pathological phenomenon, produced by a morbid state of the brain.

Berthold regards sleep as a periodical interruption of the higher vital manifestations, characterized by the descending to a lower degree in the scale of organic life; so that in sleep, an animal of a higher order resembles one of a lower, and the lower are brought to the condition of plants. The degree and the quantity of sleep, he supposes to be in the direct ratio to the development of the organization, and to be measured by the interval, which separates the highest from the lowest manifestations of life. Hence, according to Berthold, the inferior orders of the ani-

mal world, in which this interval is small, sleep but little, and plants, perhaps, scarcely at all. Worms and insects, for example, sleep very little; the amphibia and fishes, which are higher in the scale of organization, probably sleep more, but still, according to Berthold, comparatively little; but, as we ascend higher in the scale of animal life, sleep becomes a more conspicuous and important phenomenon.

Tiedemann remarks, that, from the very constitution of the nervous system, the organs of sense and the muscles of voluntary motion, and, to a certain degree, the brain itself, are so affected by the excitations to which they are subject, and by their own proper actions, as to lose their receptivity to these excitations, and to be rendered incapable of continuing the exercise of their functions. During sleep, the constitution of the nervous system is restored to the necessary conditions by the powers of nutrition; whence its organs again become capable of acting under the influence of the agents, which are adapted to excite them.

Sleep is periodical, returning at stated times, and, in most animals, once in twenty-four hours; most animals, and man among the number, sleep in the night. The absence of the stimulus of solar light, the diminished warmth, the comparative stillness of night, the exhaustion of the animal powers by the labors of the day, all contribute to render the night a suitable time for sleep. Some animals, however, sleep most in the day, and are awake during the night, as the cat, the fox, the otter, &c.

Certain animals sleep several months during the winter, and some during the summer months. Among the mammiferous animals, the bear, the badger, the hedge-hog, the marmot, the bat, &c. are hybernating animals. Some among the feathered tribe, and many of the amphibia, also, become torpid during the winter months; and the same is true of some of the invertebrated animals. According to Humboldt, the *Erinaceus caudatus* sleeps three months in summer. In this state of torpor the temperature of the animals

falls very much, their secretions are diminished, their excretions suppressed, their respiration very slow and scarcely perceptible, their circulation very much diminished, and sensibility to external irritations suspended. Hematosis is imperfect, and hence their arterial blood differs less from venous blood than in their waking intervals. A remarkable circumstance is, that the liver, in hybernating animals, becomes enlarged during their winter's sleep.

Very frequently sleep is imperfect, and, instead of involving all the animal functions, seizes upon some of them only, leaving the others in a state of greater or less activity, and permitting a partial intercourse with the external world.

There are several varieties of imperfect sleep. In some instances, certain sensations are felt; as, for example, when a person asleep changes his posture, or draws the bed-clothes over him, or, as frequently happens with infants, kicks them off. The same facts prove, that voluntary muscular power may be excited in sleep, and consequently that intellectual determinations may still be formed. Besides, persons sometimes sleep in such postures as require an exercise of some of the voluntary muscles; as, for example, when a person falls asleep sitting in a chair, or on horseback, or even, as sometimes happens, when standing up.

Dreams.

Very frequently some of the intellectual operations are carried on during sleep, constituting the phenomena of dreams. All the faculties of the understanding, the perception, memory, imagination, invention, reasoning, judgment, &c. may be the subjects of this phenomenon. In the fanciful but beautiful language of Bichat, dreams are a portion of animal life, escaping from the torpor in which the rest of it lies buried.

Dreams are excited by various causes; sometimes by the state of the brain, this organ not being completely asleep, and continuing to exercise some of the functions which are usually suspended in sleep; some-

times by sensations, powerful enough to be felt, but not enough so to wake the subject from sleep; as, for example, a loud sound, an uncomfortable posture, the stimulus of urine distending the bladder, thirst, hunger, pain, an overloaded stomach, &c.

A remarkable circumstance respecting dreams, is, that we mistake our ideas for actual perceptions, and suppose that the trains of images, which pass through our minds, represent scenes which actually exist. This is probably owing to the circumstance, that, during sleep, the senses are incapable of admitting external impressions; and that, of course, we do not receive sensible impressions, with which we may compare the ideas which arise in our minds, and learn the difference between the two. Such a comparison is constantly, though unconsciously, made during our waking hours; and hence there is no danger of confounding the images which arise in our minds, with actual impressions on the senses. But in sleep we have no such means of correcting the illusion; and as the ideas and images, which pass through our minds in sleep, constitute at this time our highest, and indeed our only, consciousness; and as experience has uniformly associated the exercise of consciousness, in our waking hours, with the presence of external objects, it seems unavoidable, that, in such circumstances, we should give credence to our ideas, as representations of objects really existing.

The train of ideas in the mind, during sleep, except so far as it may be disturbed by sensations accidentally excited, which may direct the current into different channels, is regulated by spontaneous associations, in which volition and the judgment, which are now dormant, have no share; and hence, the absurd and inconsistent ideas, of which our dreams are generally composed.

Somnambulism.

In some cases of imperfect sleep, the muscles of locomotion and those of the voice, retain their power

of action, while the external senses remain buried in repose. This state constitutes that curious affection, termed Somnambulism, which may be regarded as a greater degree of dreaming.

The phenomena of somnambulism may be reduced under the following heads; 1. suspension, more or less complete, of the external senses, and a state of isolation from the external world, and, in some instances, extraordinary increase of power of vision and external feeling; 2. a concentration and increase of energy of the powers of the mind, owing, perhaps, to their not being distracted by impressions upon the senses, but exclusively occupied with their own peculiar actions; 3. the power, in some cases, of communicating with a somnambulist, who can neither see nor hear, by touching some part of his body, and thus of enabling him to understand and converse with you; 4. to these may be added, that sleep-walkers generally have no recollection whatever, after they awake, of what they had done and said while asleep.

1. Somnambulists, like persons in ordinary sleep, are not sensible to external impressions. Sometimes their eyes are wide open, yet are so insensible to light, that the strong light of a lamp may be thrown directly upon them without producing the slightest indication of their perceiving it. The sense of hearing, also, is frequently entirely suspended. Sleep-walkers are sometimes so deaf, as to be apparently insensible to the loudest sounds, excited close to their ears. The sense of smell, also, is sometimes so entirely suspended, that the most pungent odors, as that of strong hartshorn, held directly under the nose, apparently do not excite the least sensation.

One of the senses, however, viz. that of touch, appears to be in a state of extraordinary activity and acuteness.

Sometimes the external senses are not suspended, but are in a very peculiar state. A sleep-walker once rose from his bed, with his eyes shut, lighted a lamp, and began to write by it. A person, who happened to see him, purposely extinguished his light; and

though there were others burning in his chamber, he did not appear to see by them, but seemed to be plunged in profound darkness, and went and lighted his lamp again.* Persons engaged in literary occupations have been known to get up in their sleep, go to their writing-desk, and begin their usual business of writing, and even to continue it, after an opake substance had been purposely interposed between their eyes and the paper they were writing upon. There is a story of a young ecclesiastic, who would sometimes get up in his sleep, write his sermons, and correct them with the greatest care; compose music, and write it off carefully, and recopy it, if he thought it incorrect, and review it with the greatest attention—and all this with his eyes shut, and even with a sheet of paper held between his eyes and the paper on which he was writing.

These facts were deemed incredible by some, until the extraordinary narration of Jane Rider fully established the fact, that a somnambulist may enjoy perfect vision with the eyes closed, and even covered with a thick bandage. In one experiment, the author of the narrative informs us, that he took two large wads of cotton, and placed them directly on the closed eyelids, and then bound them on with a black silk handkerchief. The cotton filled the cavity under the eyebrows, and reached down to the middle of the cheek, and various experiments were tried, to ascertain whether she could see. In one of them, a watch inclosed in a case was handed to her, and she was requested to tell what o'clock it was by it; upon which, after examining both sides of the watch, she opened the case, and then answered the question. She also read, without hesitation, the name of a gentleman, written in characters so fine, that no one else could distinguish it at the usual distance from the eye. In another paroxysm, the lights were removed from her room, and the windows so secured that no object was discernible, and two books were presented to her,

* Dict. de Medicine.

when she immediately told the titles of both, though one of them was a book which she had never before seen. In other experiments, while the room was so darkened, that it was impossible, with the ordinary powers of vision, to distinguish the colors of the carpet, and her eyes were also bandaged, she pointed out the different colors in the hearth rug, took up and read several cards lying on the table, threaded a needle, and performed several other things, which could not have been done without the aid of vision.

It is also remarkable, that somnambulists will go about in the dark with their eyes closed; with the utmost security avoid obstacles in their way; open windows, and get out of them; climb up on the roofs of houses; and apparently take pains to get into situations of great peril, from which they extricate themselves with extraordinary adroitness and skill. A gentleman once informed the author, that he awoke one night, and, to his astonishment, found himself swimming in the midst of a pond. It is impossible to doubt, that, in such cases, they enjoy the power of vision. It is stated, in the narrative of Jane Rider, that, night after night, she was seen to perform things which it seemed impossible for her to do without the aid of vision. Her friends were convinced that she saw when her eyes were closed and in the dark. When obstacles were placed in her way, or the position of a thing was changed, she always observed it, and accommodated herself to the change.

Sometimes, instead of being deaf, sleep-walkers appear to hear sounds, and are easily awaked by them; and, what is very remarkable, they sometimes hear and understand what is said to them, answer questions, and even carry on connected conversations, without waking up. Jane Rider, in her paroxysms, we are told, heard, felt, and saw, but the impressions on her senses had no tendency to waken her.

2. While the external senses are in this singular state, the faculties of the mind, in some instances, acquire an extraordinary degree of energy and power; and a sleep-walker sometimes will perform things

which he could not possibly do when awake. Somnambulists have sometimes composed poetry, performed mathematical calculations, and discoursed in a style much beyond their ability in a waking state. These facts seem to prove, that, during somnambulism, the external senses, being closed, as it were, to the external impressions which excite them during the waking hours, there is a concentration of power in the faculties of the mind, which acquire an unusual degree of energy and activity.

3. Another very curious and remarkable fact, which has sometimes been observed, is, that a somnambulist, though in a profound sleep, and deaf to very loud noises, can yet be made to hear and to understand another person, and reply to his questions, if the latter places his hand upon the pit of the sleeper's stomach, or perhaps merely touch any part of his body; and yet will remain wholly insensible to the voices of others around him, and speaking at the same time.* A fact of this kind is related by Dupau, in his "Lettres sur le Magnetisme," and others have been mentioned to the author.

4. Somnambulists, when they awake, have no recollection of what they had said or done while asleep. Not the slightest impression of what had occurred during the paroxysm, seems to remain on the mind after they awake. In some rare cases, somnambulists have appeared to possess a double consciousness and memory, i. e. in the paroxysms to retain the knowledge which they possessed in previous paroxysms, but to forget every thing they had known in the intervals; and in the intervals, to remember all they had known in previous intervals, but to forget every thing they knew in the paroxysms. Somnambulism appears to partake of the nature of certain cerebral diseases, as ecstasies, catalepsy, and epilepsy. Prichard considers it as a morbid modification of ordinary dreaming.†

* Dict. de Medicine, Magnetism Animal.

† Diseases of the Nervous System.

CHAPTER XXXI.

Animal Magnetism.

In this chapter I shall give a brief account of some of the alleged facts, in relation to the subject of animal magnetism, without expressing any opinion respecting the truth of these extraordinary statements. I am induced to insert a short notice of this subject, from the fact that it has attracted a considerable degree of interest, of late years, in some parts of Europe, and that several distinguished men have enrolled their names among its disciples. For the following account, I am indebted chiefly to the article on animal magnetism, in the Dictionaire de Medicine, by Rostan, and to Georget's Physiologie du Systeme nerveux.

The expression, animal magnetism, is used in different senses, either to signify a peculiar state of the nervous system, giving rise to a series of phenomena, of a very extraordinary kind, and produced by a certain influence, exerted by another individual upon the person who exhibits them; or, secondly, to denote the processes which are employed to produce these effects.

We are told, that, as two individuals are necessary in performing these processes, certain conditions in the two, are necessary for the success of the experiment. On the part of the person who is to be the subject of the magnetic influence, is required a nervous temperament, and a feeble and excitable constitution. Females, subject to epilepsy, catalepsy, or other nervous disorders, are well adapted to the manifestations of the magnetic influence. In most instances, it is also necessary that the subject feel a willingness to submit to the experiment, and a disposition to yield to the influence of this extraordinary agent. This condition, however, is not indispensable, though it is extremely

favorable to the success of the experiment. Persons have been thrown into a state of magnetic somnambulism without their knowledge of the means employed; and others, in spite of a strong repugnance to the experiment, and their earnest entreaties that the magnetizer would desist.

On the part of the magnetizer, or the person who exerts this influence, are required also certain conditions. One of these is, a strong and energetic exertion of the will, a vivid desire to produce the effects in question, and a full conviction that he shall succeed in his attempts. The necessity of these moral dispositions in the two parties has given rise to no little ridicule in the opposers of animal magnetism, who forget that the magnetic action is owing to a peculiar state of the nervous system, and that the moral dispositions required in the parties, are themselves only certain states of the nervous system.

When these conditions exist in the two parties, the magnetic influence may be exerted by different processes. The following method may serve as a specimen. The operator places the other party on a seat before him, so that the knees and the ends of the feet may touch, and then grasps the thumbs of the other party with his two hands, and holds them until the temperature of both is the same. He then places his hands upon the two shoulders of the other party, and, after a few moments, moves them down the arms, taking care to follow, with the ends of his fingers, the course of the principal nerves, as they pass down the arms. This is to be done several times. The hands are afterwards to be applied to the pit of the stomach, and to remain there until the heat between the two parts become equalized; then to be carried down the trunk of the body, to the lower limbs.

These movements are to be repeated several times, after which some of the magnetic phenomena usually begin to manifest themselves. The patient begins to experience a feeling of heaviness and confusion in his head, yawns, stretches his limbs, becomes drowsy,

drops his upper eyelids, and, at last, falls into a deep sleep.

After a few trials, we are told, it is not necessary for the magnetizer to apply the hands, at all, to the other party. It is sufficient to order him to go to sleep; and he will immediately obey, without the power of resisting the commands of the magnetizer. Some apology may seem necessary for inserting such absurd and improbable fictions. But however incredible they may seem, they are gravely asserted by such men as Rostan and Georget. The former of these declares, that, in some instances, he merely exerted a strong effort of the will, without even speaking to the subject of the operation, when the latter began to yawn and stretch, and to manifest some of the other signs which precede sleep, and cried out, "What are you doing to me? I beg of you not to make me go to sleep; I do not wish to go to sleep." And Georget asserts, that he had several times been witness to an exertion of the magnetic influence, by the mere energy of the brain, or of the will of the magnetizer, and even at a distance of several feet, and in cases where the two parties were separated by a door or a partition, and the patient had no suspicion of what was going on.

Such are the methods by which magnetic sleep may be induced. The phenomena which this singular state exhibits are extremely curious, and well worthy of physiological investigation. In many respects they resemble those of common somnambulism; in others, they present some striking peculiarities.

In magnetic sleep, the subject seems to be shut out, as it were, from the external world, and to live only in himself. The senses, especially those of sight and hearing, are entirely suspended. The magnetized sleeper does not appear to hear the loudest noises, nor to see the brightest light. Even the report of a pistol fired close to his ear, occasions no starting, nor any other motion, nor does it prevent his carrying on a conversation already commenced, in an unaltered tone of voice. But a remarkable circumstance, in

which magnetic sleep resembles common somnambulism, is, that if the magnetizer touch the body of the sleeper with his hand, the latter immediately acquires the power of hearing and understanding the magnetizer, though he remains incapable of hearing any other person.

The eyes, also, in most cases of magnetic sleep, are wholly insensible to light. In some cases, the flame of a lamp has been brought so near the eyes of the *sleeper*, as to scorch his eyelids, without his manifesting the least sign of sensation. The eyelids are closed and applied firmly and almost convulsively to the eye, so as not to be raised without some difficulty. But if the eye be forcibly opened, the eye-ball is found to be rolled up and fixed by a spasmodic action of the muscles of the eye-ball, so that only the white of the eye can be seen. When the pupil is visible, it is observed to be dilated. Even when the eye is opened, it sometimes remains wholly insensible to light. In other cases, the flame of a lamp has produced the impression of a faint whitish light.

The sense of touch is in a very extraordinary state. Sometimes it acquires an astonishing degree of acuteness, so as to become capable of receiving impressions, and of communicating ideas to the mind, which are entirely foreign to its ordinary functions. A person in a magnetic sleep, incapable of seeing or hearing, will distinguish in a moment between different individuals, who touch him, if it is merely with the end of a finger. Sometimes these sleepers are aware of the presence of persons, who enter the apartment after they have ceased to see or to hear, who carefully avoid making the slightest noise, and who do not even touch them. Though incapable of seeing or hearing, they are, by some means or other, aware of the objects and of the individuals around them; perhaps in the same manner as the deaf and blind child at Hartford. They avoid, with the greatest care, obstacles lying in their way, which, however, is no more than is frequently done by common sleep-walkers. A most extraordinary experiment made by a French

physician, and related by himself, if it does not wholly exceed the bounds of credibility, will afford a striking illustration of the state of the senses in this strange affection. The experiment is the following, which the writer says he had frequently performed. He took his watch, and placed it three or four inches *behind* the head of a person in a magnetic sleep. He then asked her, if she saw any thing.—"Certainly," said she, "I see something which shines—it hurts me." Her countenance at the same time became expressive of pain. He then said to her, that if she saw some shining object, she could immediately tell what it was. She expressed great reluctance to tell; but, upon being urged by the experimenter, and complaining of the exertion fatiguing her, after a moment of deep attention, she said, "It is a watch." She was then requested to tell what o'clock it was by the watch; her reply was, "Oh no, it is too hard;" but, upon being again urged to say, she reluctantly consented, and after an effort of great attention, she said, "It wants ten minutes of eight o'clock;" which was exactly true. Astonished at this result, another gentleman who was present, M. Ferrus, after repeating the experiment himself, with the same success, proposed that they should alter the position of the hands of the watch. This was accordingly done several times, and the watch each time placed as before, a few inches behind the head, and, in every instance, the subject of the experiment mentioned the time indicated by the watch, with perfect accuracy. In one instance when the watch was placed *before* her, she mistook the position of the minute hand, though not its distance from the twelve o'clock mark, saying it wanted so many minutes of the hour, when in fact it was just so many minutes after, and vice versâ. "Here then," says Rostan, "we see the power of vision transferred from the eye to other organs, which exercise no such function in the natural state." In order to diminish the extreme improbability of such a supposition, Rostan remarks, that plants are undoubtedly sensible to light, without having any organ of vision or even any ner-

vous system; and that probably many of the inferior classes of animals, though destitute of eyes, are sensible to light by the whole surface of their bodies. Worms, for example, retreat into their holes at the light of a lamp. The sensibility which, in man and the inferior animals, is divided into five different species, and distributed among five distinct organs of sense, he supposes to exist in the lowest animals, in all its modifications, in every part of the skin. If this be admitted in regard to the lowest orders of the animal world, where, he asks, is the extreme improbability in the supposition, that when the proper organs of sight in the human species, are deprived of the faculty of vision, the power, under some circumstances, may be transferred to another organ of sense, which we have reason to believe possesses and exercises it in some other animals? Why cannot we suppose, that the nerves expanded over the skin, and which are the seat of common feeling and touch, may become endued temporarily with the peculiar modes of sensibility which exists in the nerves of seeing, hearing, smelling, &c.? This view corresponds with that of Berthold, who says, that, in magnetic sleep, the senses lose their individuality and their peculiar distinctive characters, and become fused, as it were, with the functions of the nervous system of vegetative life; and, in the same degree as the senses lose their distinctive powers and become *indifferent*, the power of common sensation is exalted, and endued occasionally with the senses of seeing, hearing, &c.* This hypothesis must go for what it is worth. It is proper, however, to state here, that the sensibility of the skin in magnetic sleep is very great, and the patient is unable to bear the least degree of cold.

Such are some of the principal facts relating to the state of the senses and of sensation. But we are told, that the condition of the powers of sensation may be influenced anew by an additional application of magnetic power. The senses may be completely paralyz-

* Berthold, Lehrbuch der Physiologie.

ed, and rendered wholly insensible to external impressions, so that the subject of the experiment may be incapable of hearing even the magnetizer himself; the sense of smell so completely suspended, that the strongest hartshorn may be applied to the nose, and kept there for several minutes, without exciting sneezing, or any appearance of uneasiness, or, in the slightest degree, affecting the breathing. The skin also may become so insensible, that pinching it black and blue, or running sharp instruments into it, will excite no feeling; and it is not affected by the application of hot water, or even that of fire. This second application of magnetism may be made without the knowledge, or even suspicion of the patient. The extreme insensibility induced by animal magnetism, is illustrated in a most striking manner by the following extraordinary case, related in a report made on the subject of animal magnetism, by a committee of the medical section of the French Royal Academy of Sciences, laid before this body in June, 1831.

A lady, aged sixty-four, had a cancer of the breast, for which she was magnetized, with no other effect than that of throwing her into a profound sleep, in which all sensibility appeared to be annihilated, while her intellectual operations were carried on with their usual activity. It occurred to the lady's medical adviser, M. Chapelain, to perform the operation of cutting out the cancer, while she was plunged into this profound sleep; and he accordingly proposed the idea to M. Jules Cloquet, the surgeon. The latter deeming the operation indispensable, consented—as a preliminary step the lady was magnetized several times, the two evenings previous to the operation; and in this state was prevailed upon to submit to it; although, when awake, she rejected the idea with horror.

On the day fixed for the operation, Cloquet arrived at half past ten o'clock, A. M. and found the patient seated in an elbow chair, in the attitude of a person enjoying a quiet natural sleep. She had been magnetized by her physician, and thrown into a state of magnetic sleep, and was conversing with great calm-

ness on the subject of the operation she was about to undergo. Every thing being arranged for the operation, she adjusted her dress, and sat down on a chair. Being properly supported by her physician, the first incision was commenced at the arm-pit, and was continued beyond the tumor. The second commenced at the same point, and was continued until it met the first; the enlarged ganglions were dissected out with caution, on account of the vicinity of the axillary artery, and the tumor was extirpated. The duration of the operation was ten or twelve minutes.

During all this time, the patient continued to converse quietly with the operator, and did not exhibit the least sign of sensibility. There was no motion of the limbs or of the features, no change in the respiration nor voice, and no alteration in the pulse. There was no occasion of confining the patient, but only of supporting her. The wound was dressed and the patient put in bed, while still in a state of magnetic sleep, in which she was left forty-eight hours. The wound was then dressed again, and the patient still exhibited no indication of pain, or sensibility. Two days after the operation, the lady was awaked out of her magnetic sleep by the physician, and she appeared to have no knowledge nor suspicion of what had occurred.

The muscles of voluntary motion are also subject to the magnetic influence. We are told, that any of the limbs or muscles of the patient may be rendered completely paralytic, by the will of the magnetizer; an effect which, however incredible, Rostan declares is most easily and most frequently produced, and which, indeed, he says, *scarcely ever fails!* You have only, says Rostan, to will that a certain limb of a patient shall not move, and two or three gestures are sufficient to throw it into a state of complete paralysis, in which the patient will find it absolutely impossible to move it in the slightest degree; and before he can recover the power of moving it, it must be *deparalyzed* by the magnetizer. Indeed, this astonishing effect may be produced mentally; that is, by a mere exertion

of the will, without any accompanying gestures, so that the patient can have no suspicion of the intention of the magnetizer. Rostan says, that he has frequently, in the presence of witnesses, paralyzed any limb, that he was requested to affect in this mode, by *a mere effort of his will!* A bystander has been put in communication with the patient, so as to converse with him, and on being desired by the former to move the limb, the subject of the experiment has found it in a state of absolute paralysis. If the tongue be paralyzed in this manner, which we are told *is very easily done*, and a question then be put to the somnambulist, he will make violent efforts to speak, but to no purpose. His face will swell and become flushed with the exertion, and his features express the most painful efforts, yet not a word can be got out. Georget informs us, that he once made an experiment to ascertain whether the muscles of respiration situated about the chest, could be affected with magnetic paralysis,—when, to his great alarm, he perceived that the chest became entirely motionless, and the patient appeared to be in imminent danger of suffocation. If the patient be roused from his sleep by the magnetizer, without having his tongue or his limbs or his senses previously *deparalyzed*, this palsy continues, and nothing, it is said, can exceed the surprise and fright experienced by the patient, when upon first waking he finds himself unable to speak, or to move his arms or his legs, or perhaps perfectly deaf.

When a limb or a muscle is subjected to the magnetic influence, the patient at first feels extreme coldness in the part, which is soon followed by prickling, and a feeling of weight and numbness. At length it becomes stiff or rigid, and loses all power of motion and sensation. In a little while it becomes cold, and sometimes has the peculiar whiteness which the fingers exhibit, after exposure to severe cold.

The state of the mental faculties, in magnetic sleep, remains to be noticed. In many respects the state of these faculties resembles their ordinary condition. Persons under the influence of animal magnetism ex-

ercise their powers of intelligence, like those who are awake. They think, talk, laugh, reason, &c. as they do in ordinary circumstances, though their senses are affected in the singular modes above described. But the state of their mental powers presents some remarkable peculiarities. A person in a magnetic sleep has a perfect recollection of all that has passed on all former occasions of the same kind; but he loses this recollection entirely as soon as he awakes, and recovers the whole of it when plunged into magnetic sleep again. He seems, indeed, to possess two existences, entirely separate from each other. When awaked, he forgets every thing which he had said or done, or that occurred to him, while in a state of somnambulism; but remembers the whole of it again, whenever this state is renewed. Besides this remarkable double memory, this faculty of memory acquires a strength, far beyond its ordinary power. Magnetic sleepers sometimes recite with the utmost correctness long pieces of poetry, which they had learned and forgotten, or which, perhaps, they had only read. Their internal perceptions acquire an acuteness and vividness, to which, at other times, they are strangers. Persons of very ordinary capacity seem to acquire, by the magnetic influence, a keenness of perception, a strength of judgment, and a vividness of imagination, which forms a striking contrast with their usual mediocrity of talent and temperament. One writer observes, that they appear to soar in a more elevated region. Every thing is dignified and embellished by the power of their minds. They paint objects in the most brilliant colors, and they display a power of eloquence, and a richness of language, wholly disproportioned to their ordinary ability and habits of mind.

It is also extremely remarkable, that the will of the somnambulist seems to be entirely under the control of the magnetizer. It appears, indeed, to be nothing but an instrument in his hands, which he directs and uses at pleasure. The somnambulist acts only through him; his desires, his thoughts are influenced

by him; even his muscles and limbs and senses become paralyzed at the command of the magnetizer. The latter can extract from him his most secret thoughts, and compel him to disclose facts or circumstances within his knowledge, affecting his own character or interest, or those of others, and which he may have the strongest motives to keep inviolably secret. The magnetizer has the key of his cabinet, and can open it and examine its contents whenever he pleases. Notwithstanding the extreme improbability of many of the realleged facts relating to animal magnetism, there are several phenomena of ordinary somnambulism, and of certain nervous diseases, which indicate states of the nervous system, very similar to those which must be supposed to exist in magnetic somnambulists, if the statements on this subject be admitted to be true. Even ordinary sleep presents some phenomena very similar to those of magnetic sleep. In common sleep, there is a *universal* paralysis of sensation and muscular motion, frequently accompanied with an active state of the intellectual and moral powers. The magnetic sleep, then, is a paralysis of sensation, with an active state both of the mental and of the muscular powers—and the same is the fact in common somnambulism. The power of distinct vision, where the eyes are shut and covered with bandages, appeared to be one of the most incredible fictions of the magnetizers, until the authentic narrative of Jane Rider proved to us, that the same astonishing phenomena may occur in common somnambulism. The power of hearing and of carrying on a conversation, when plunged in sleep, is not peculiar to persons under the influence of animal magnetism; for, common somnambulists sometimes do the same. Dupau relates the case of an officer, who, from his infancy, enjoyed the power of hearing and understanding what was said to him, while asleep, and of answering questions, without waking up. One day, several of his friends, having surprised him asleep in his chamber, began to converse with him, and received brief, but pertinent answers to their questions. One of them designedly

used some insulting language to the officer, which the latter resented with great indignation, and the quarrel at last became so warm, that a challenge passed from the other party, and was accepted on the spot: a pistol being placed in the hand of the officer, he presented it and fired, and was waked by the report; and was astonished to find himself among a party of his friends, who were highly amused at the scene. This officer, in his sleep, retained his sense of hearing, and by this means, another person could converse with him, without his waking up; but it was necessary, in some other cases of somnambulism, and as it is also something in magnetic sleep, for the other party to *touch some part of his body*, in order to make him hear.*

The paralysis of the muscles, which we are informed may be produced by the magnetic influence, has a counterpart in some cases of imperfect sleep. The author has, in numerous instances, fallen into a state of partial sleep, in which his consciousness was not suspended, nor his senses asleep, and yet no effort he could exert, would bring any of his muscles into action. The sense of helplessness was most distressing, and induced violent efforts to break the spell—but his limbs were fettered down immovably to the bed. Now, if the whole muscular system may be reduced to a state of temporary paralysis, while the senses, also, are in a state of repose, as in common sleep, or while the senses are awake, as in the state of imperfect sleep just mentioned, where is the extreme improbability, that a *part only of the muscular system* may be reduced to the same state of temporary paralysis, as is alleged to happen in some cases of magnetic sleep? The truth seems to be, that, as perfect sleep involves *all* the functions of animal life, imperfect sleep may affect *any part*, or, for any thing we know to the contrary, *any one* of them. If, in ordinary somnambulism, one of the senses may be awake, and even in a state of preternatural acuteness, while the others are wholly locked up from external impressions, how

* Lettres sur le Magnetisme Animale.

do we know, that some part of the muscular system may not be deprived of all power of action, while all other parts of it retain this power in the fullest degree? So far as this, there appears to be nothing incredible, or even very improbable, in the accounts of the state of the system, when under the magnetic influence. But, with regard to the transfer of the functions of one sense to the organs of another, the case is different, and derives no support from the analogy of common somnambulism, or imperfect sleep. The same is true of the pretended *clairvoyance* of magnetic sleepers.

It is worthy of remark, however, that the author of the narrative of Jane Rider, in order to account for the fact of her being able to see distinctly in the dark, with thick bandages over her eyes, is compelled to resort to a supposition, which is almost as difficult to admit as the transfer of the office of one sense to the organ of another. He observes, that, for a person to see external objects, it is necessary that a *distinct* image of the object be formed on the retina, even though it be a *faint* one. Now, he admits that the rays of light, in passing through a bandage, or through the eyelids, are so variously refracted that no distinct image can be formed. If this be so, it may be asked, how was it possible for Jane Rider to see *distinctly*, under such circumstances? To answer this question, the author resorts to the supposition, that a change takes place in the state of the brain, a certain excitement of the organ, in consequence of which, perception, so far at least as relates to this order of impressions, is affected more readily than usual. "In this way," says the author, "we can conceive, that it would be possible for even a confused image to be perceived." This ingenious supposition of the author would be more admissible, if it were easy to conceive that any image could be formed by the light, that could struggle through a thick wadding of cotton, enveloped in a black silk handkerchief, applied over the closed eyelids of a person in a dark room. In passing through such a thickness of substances, nearly opake, the very few

rays of light that might eventually work their way through, would undergo innumerable refractions before they reached the eye; so that it is not very easy to conceive in what manner any image at all could be formed; unless we suppose the eye to possess the power of restoring the dislocated rays to the directions, in which they emanated from the objects, as well as of refracting them afterwards to foci on its own retina.

The excitation of the intellectual powers, and the phenomena of double consciousness, are common to magnetic and ordinary somnambulism.

But one of the most incredible things in the accounts of the magnetizers, is, that such extraordinary states of the system should be produced by means apparently so inadequate, as quietly stroking the body and limbs of the subject, or making a few unmeaning gesticulations, or merely exerting an act of the will. In respect to the last named means, in particular, it appears wholly inconceivable, that it could transmit any influence from the magnetizer to the other party, notwithstanding the ingenious theory of magnetism, proposed by Rostan. We should not forget, however, that the human body, in certain states of the nervous system, is sensible to certain influences or emanations, which are wholly imperceptible to it under all other circumstances. Caspar Hauser, we are told, was extremely sensible to the influence of common magnetism, and to metallic emanations. On one occasion, Professor Daumer placed a gold ring, a steel and brass compass, and a silver drawing-pen under some paper, so that it was impossible for him to see what was concealed under it. He was then directed to move his finger over the paper without touching it. He did so, and was able accurately to distinguish all these metallic substances from each other, according to their respective matter and form. When Daumer held the north pole of a magnet towards him, Caspar put his hand to the pit of his stomach, and said, that it produced *a drawing sensation*, and that a current of air seemed to proceed from him. The south pole

affected him less, and he said that it *blew upon him.* He displayed this extraordinary sensibility to metallic influences, on many other occasions. We are also told, that animal emanations affected him in a manner equally surprising; and he called the streaming of the magnetic fluid upon him, a *blowing upon him.* These sensations he experienced, not only when in contact with men, but when they extended the ends of their fingers towards him, at some distance; and even when he touched the inferior animals. When he laid his hand upon a horse, he said, that a cold sensation went up his arm. When he caught a cat by the tail, he was seized with a fit of shivering, as if he had received a blow upon his hand.

Before dismissing this subject, it may not be improper to notice the opinions of some distinguished men, who have paid attention to it, and who will scarcely be suspected of any excess of credulity.

The committee of the medical section of the French Royal Academy of Sciences, it appears evident from their report on animal magnetism, were staggered by the extraordinary facts which they had witnessed; and were compelled to give a reluctant assent to the pretensions of the magnetizers; though they seem almost afraid of disclosing their convictions of the reality of this specious *thaumaturgy.*

"We do not (say they) demand of you a blind belief of all that we have reported. We conceive, that a great proportion of these facts are of a nature so extraordinary, that you cannot accord them such credence. Perhaps we, ourselves, might have ventured to manifest a similar incredulity, if, changing characters, you had come to announce them to us; and we, like you, had neither seen nor observed, nor studied, nor followed any thing of the kind."

To this remarkable testimony, of some of the most distinguished medical men in Paris, may be added the following, from two of the most illustrious characters of the age, Cuvier, and Laplace, as cited by Rostan, in the Dictionary de Medicine.

Cuvier remarks on this subject, in the following manner: "It must be confessed that it is very difficult, in the experiments made, in order to ascertain the natural influence of the nervous system of two different individuals upon each other, to distinguish the effect of the imagination of the person who is the subject of the experiment, from the physical effect produced by the other. Yet the effects produced, on persons already in a state of unconsciousness, before the experiment began, on others, after the experiments themselves, had produced a suspension of consciousness, and those which animals sometimes exhibit, scarcely permit us to doubt, that the proximity of two living bodies, in certain positions, and with certain movements, is capable of producing a real effect, independent of all participation of the imagination of one of the two parties. It, also, clearly appears, that these effects are owing to some kind of communication, established between their two nervous systems."

The celebrated Laplace expresses himself on the same subject, in the following terms:—

"The singular effects, which result from the extreme sensibility of the nerves in certain individuals, have given birth to different opinions on the existence of a new agent, which has received the name of animal magnetism. It is natural to think, that the action of these causes is very feeble, and may easily be disturbed by a great variety of accidental circumstances; so that, from the fact, that, in many cases, this agent has failed to manifest itself, we ought not to conclude that it never exists. We are so far from being acquainted with all the agents in nature, and their different modes of action, that it would be unphilosophical, to deny the existence of phenomena, merely because, in the present state of our knowledge, they are inexplicable.

CHAPTER XXXII.

Death.

Every organized living being is subject to death, i. e. a cessation of its living functions, and the return of the organized matter, of which it is composed, to the jurisdiction of the physical laws of nature. Death has been defined "the irrevocable cessation of those functions, which bestow, on organized living beings, the power of resisting * the destructive influences with which they are surrounded."

Death may happen at different periods of life, in different modes, and from various causes. A period is assigned by nature in every organized being, for the cessation of life; and, whenever death happens in conformity with this law, it may be termed *natural* or *senile* death. Every other kind of death may be called *accidental*.

Natural death, is that which occurs when the vital mechanism has passed through all its periods; and it is the result of the gradual deterioration or wearing away of the organization by the operations of life, in consequence of which the organs and tissues gradually lose the predominance, which they previously held over the physical and chemical forces of matter, maintain for a time a feeble contest with them, but at length become victims in the unequal struggle. The nature of the deteriorations of the organization, which lead to natural death, is unknown. Different physiologists have assigned different changes, as e. g. the ossification of the arteries, producing an obstacle to the free distribution of blood; the ossification of the costal cartilages; the diminution of the capillary system of the lungs, causing an imperfect hematosis; a

* Lepelletier.

gradual shrivelling or atrophy, and induration of the nervous system, rendering it incapable of effecting its important function, viz. innervation. Adelon remarks, that, as life consists in the reciprocal action of arterial blood, and of the nervous influence, it is natural to suppose, that, in general, death, and particularly, senile death, is owing to a cessation of one or the other of these two actions; and hence, he supposes that gradual changes in the lungs, leading to an imperfect hematosis, and an atrophy and induration of the nervous system, gradually destroying the function of innervation, are two common causes of death. But these gradual changes in the lungs and the nervous system, are themselves the results of some ulterior causes; and in the present state of our knowledge, he considers it impossible to determine what these causes are.

It is remarkable, that, though senile death is most conformable to the laws of nature, one might naturally suppose it would be the most usual kind of death; yet, in fact, very few individuals die of old age. An immense majority die prematurely of *accidental* deaths; some in the embryo state, vast numbers in infancy, and multitudes of others before reaching the natural time of human life.

Accidental death.—Every kind of death which happens to organized beings, before the period assigned by nature for their duration, may be termed *accidental.* Accidental death may be owing to numerous causes, viz. 1. Defect of vital excitation, and of the reparation of the organs from a privation of air or food. 2. Accidental injuries, as blows, wounds, &c. producing mechanically or chemically a disorganization of parts essential to life. 3. The application of certain substances, called *poisons*, which corrode or inflame the organs, or else, being absorbed into the circulation, exert some destructive influence over the nervous power, and annihilate this fundamental condition of life. 4. Exposure to intense cold, and the consequent abstraction of the caloric, indispensable to maintain the actions of life. 5. Violent passions of the mind, or ex-

cessive pain, suddenly exhausting the sensibility or irritability of the organs essential to life, and occasioning sudden death. 6. Morbid changes, spontaneously produced, of organs indispensable to life; or, in other words, *disease*.

Accidental death may either occur suddenly, or be slow in its approaches. When it happens suddenly, it is owing to some destructive cause which destroys the power of one of the three great organs, most essential to life, viz. the brain, the heart, or the lungs.

The death of the brain is termed *apoplexy*. It is characterized by a suspension of consciousness, of sensation, and of voluntary motion, difficult and stertorous respiration, bloating of the face, and violent beating of the temporal and carotid arteries. It may be produced by different causes impeding the action of the brain, as, 1. *Mechanical*, including blows, concussion, compression of the brain, from effused blood, serum or pus, depressed bone, foreign substances, &c. 2. *Vital*, as for example, inflammation, or congestion, ramollisement, tubercles, &c. 3. *Moral*, as profound grief or disappointment, or other depressing passions. The death of the brain occasions universal death, by annihilating all those functions which are dependent on the cerebral energy, especially respiration, and, through this, the functions of the heart.

The death of the heart is termed *syncope*. In this kind of death, the circulation is arrested, and all the organs of the body simultaneously deprived of the presence and excitation of arterial blood, an essential condition of all vital reaction. Syncope may be occasioned by numerous causes, physical, vital and moral, as wounds of the heart, compression from water in the pericardium, ossification of the cardiac valves, &c., hemorrhages, violent pain, certain impressions upon the organs of sense, especially the sight, and smell, &c. sudden emotions of terror, &c. The death of the heart produces instantaneous death of all the great functions.

The death of the lungs is termed *asphyxia*. It produces universal death, according to Bichat, by prevent-

ing hematosis, in consequence of which, unarterialized or venous blood is transmitted to all parts of the body, and among them to the brain and the heart, which become paralyzed or poisoned by the contact of the black blood; and innervation, and the functions of the heart, are both annihilated.

Asphyxia, like apoplexy and syncope, is owing to a variety of causes; as for example, mechanical obstruction to the entrance of air into the lungs, as in drowning, choking, &c.; in dropsy of the chest, &c.; the absence of oxygen, in the air respired, or the breathing of noxious gases; inflammation or congestion of the lungs, morbid affections of the par vagum, paralysis, or want of power of the external muscles of respiration, &c. Asphyxia is characterized by a feeling of anguish, and suffocation, oppression, difficult respiration, violent efforts of the inspiratory muscles, &c. violet color of the face, lips, nails, followed by stupor, insensibility, and at last cessation of the action of the heart. In death by lightning, and by some of the narcotic and animal poisons, there seems to be a simultaneous annihilation of all the powers of life. Lightning, however, is supposed by Edwards to extinguish life, by destroying the nervous power, which, he conjectures, it effects by producing a sudden expansion of the matter of the brain and nerves.

The physiology of sudden, accidental death is not difficult to comprehend; for, we are sufficiently acquainted with the functions of the great organs concerned in it, and with their mutual relations and connections, to understand in what manner the death of the brain, the heart, or the lungs, speedily occasions universal death. But with accidental death, which approaches slowly, and seizes upon its victims by degrees, the case is otherwise. In many cases, however, even of this kind of accidental death, it is easy to discover the series of phenomena which terminates in death, because they are found to fall under one of the three classes above mentioned. Disease may be gradually developed in the brain, the heart, or the lungs, and, after a longer or shorter time, render the organ inca-

pable of performing its functions, and eventually, thus occasion accidental death by apoplexy, asphyxia, or syncope. Morbid growths in the brain, tubercles or hepatization of the lungs, ossification of the cardiac valves, &c. may thus occasion death, by a gradual approach of one of the three conditions above mentioned.

But the manner in which death is occasioned by diseases attacking organs, which are not essential to life, is not so obvious. It is not very easy to comprehend, in what manner simple fever, inflammation of the peritoneum, suppuration of the liver, dysentery, and many other diseases which terminate in death, bring on the fatal event. In all cases of death, however, one of the three great organs essential to life, the brain, the heart, or the lungs, must be primarily or secondarily affected; and perhaps it will depend either on the difference of predispositions in these organs to become affected, or on the morbid sympathies developed between the suffering organ, and one or other of these three great pillars of the living system, which shall be the first to give way, and thus to bring on universal death. In most cases, death commences either in the lungs or in the brain, and the patient expires after a distressing struggle for breath, perhaps in the full possession of his reason almost to the last gasp; or he gradually sinks into a state of stupor and insensibility, accompanied with laborious and disordered respiration, which gradually ends in death. Death by asphyxia, in acute or chronic diseases, perhaps is frequently owing to weakness and exhaustion, so much affecting the muscles of respiration, and the power of expectoration, as to render the mechanical motions of respiration more and more difficult, and, at the same time, to suffer the secretions of the bronchial tubes to accumulate, and obstruct the air passages, until, from both causes, respiration becomes impossible, and death takes place by asphyxia. In many cases, death appears to commence in the brain and in the lungs nearly at the same time. This is owing to the mutual influence which these two organs exert upon each

other; for, in asphyxia, the unarterialized blood, which is transmitted to the brain, sometimes appears to paralyze the organ, producing stupor and insensibility, which of course become combined with the symptoms of the primitive affection, asphyxia; and when death commences in the brain, the cessation of the cerebral influence, producing a suspension of the action of the external muscles of respiration, and probably of the innervation of the par vagum, so that symptoms of asphyxia become blended with those of apoplexy.

Death by syncope sometimes occurs in chronic diseases of various kinds, inducing great debility. Hydrothorax, and phthisis pulmonalis, frequently terminate fatally by syncope, though, in these cases, the syncope is complicated with asphyxia.

After death has taken place in the great vital organs, it extends by degrees to all the secondary functions of life; which successively die, until death is established over the whole system. The voluntary muscles manifest the last efforts of their vitality, in spontaneously contracting after the death of the heart and the brain; the gravid uterus sometimes contracts with so much energy as to expel the fetus; the bladder and the rectum expel their respective contents; and the capillary circulation, absorption, and even nutrition, and calorification, frequently retain their activity a considerable time after the death of the great functions.

The signs of death have been divided into the *deceptive*, the *probable*, and the *certain*.*

The *deceptive* are absence of all motions, paleness, coldness, absence of bronchial exhalation, fixedness of the eyes, dilatation of the pupils, lividness, softness of the limbs.

The *probable* are rigidity of the limbs, opacity, and sinking of the cornea, partial gangrene. The only *certain* one is *putrefaction*.

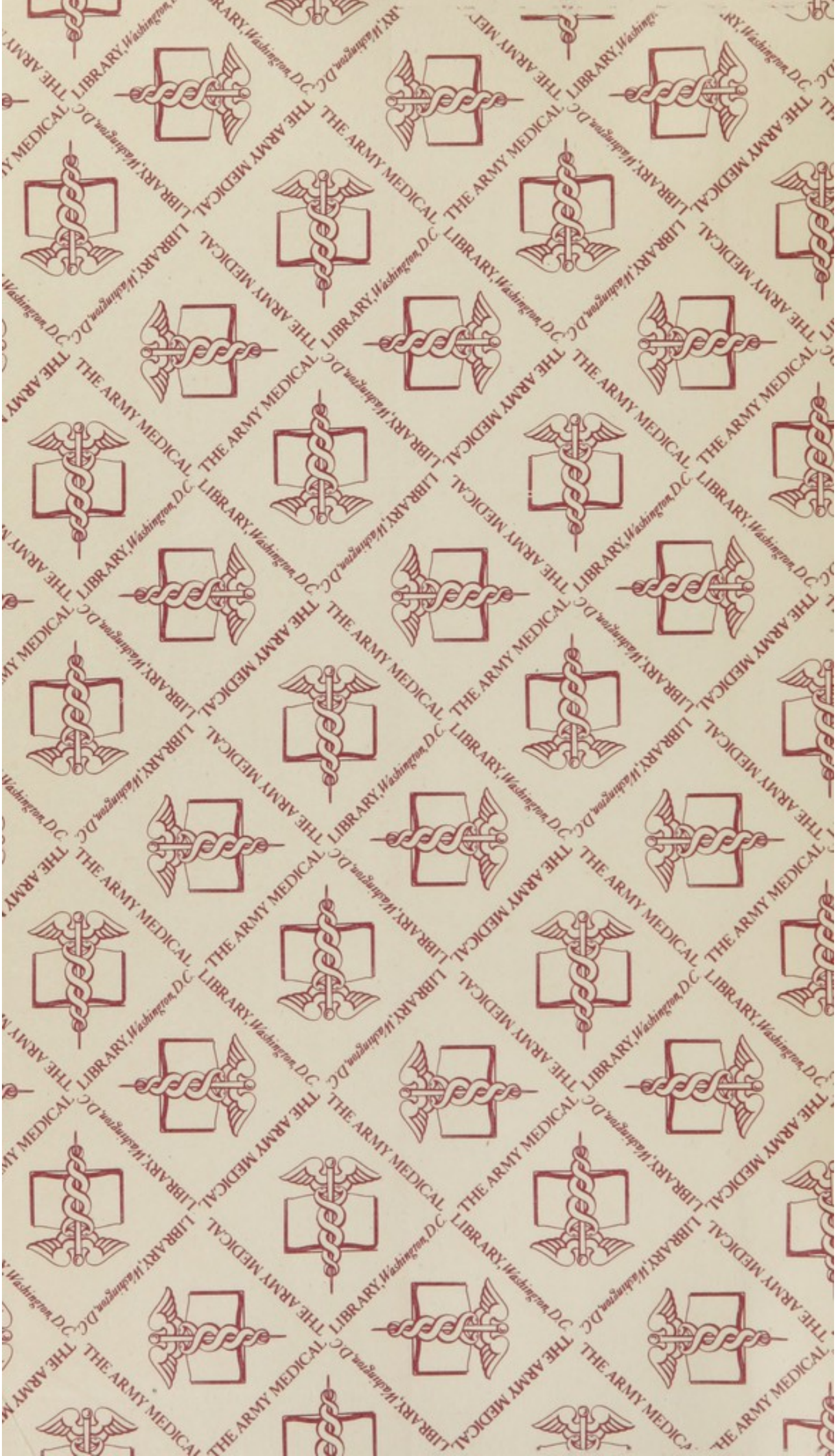
The universal death of the functions is followed by the re-establishment of the physical and chemical

* Lepelletier.

laws of nature over the now inanimate mass; the elements of which, no longer forcibly held together by the vital powers, break up their association, and, obeying their natural affinities, *pair off*, to mingle with the common mass of inanimate elements.

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