THE ELEMENTS OF PHYSIOLOGY:

CONTAINING

AN EXPLANATION

OF THE

FUNCTIONS OF THE HUMAN BODY;

IN WHICH THE

MODERN IMPROVEMENTS

IN

CHEMISTRY, GALVANISM, AND OTHER SCIENCES,

ARE APPLIED TO EXPLAIN THE ACTIONS

OF THE

ANIMAL ECONOMY.

TRANSLATED FROM THE FRENCH OF

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THE

TRANSLATOR'S PREFACE.

SINCE the time of Haller few esteemed works on Physiology have appeared; that learned and industrious investigator had, in fact, almost exhausted every source of solid information; and the very handsome manner in which his abilities are acknowledged by our author, must be highly pleasing to every grateful mind: but the progress of auxiliary sciences, particularly of chemistry, since that period, has rendered a new treatise on Physiology extremely acceptable to the medical world.

The situation of M. Richerand, as a public lecturer in this department, and principal surgeon of an hospital, qualifies him for such an undertaking; and it is presumed that the perspicuous method of elucidating various subjects, with the extensive general information diffused throughout the whole of this work, have many just claims to the approbation of the public, and particularly of professional gentlemen, who well know the difficulty of tracing, with tolerable accuracy, the functions of a living human body, a complete knowledge of which is universally admitted to be indispensably requisite in the treatment of diseases, and, when combined with anatomy, to constitute the only firm basis on which medical practice can be established.

The author's preface sufficiently explains the plan and diction of his volume. The translation is as strictly literal as the languages will admit; but since translation should be the act of rendering *ideas*, and not merely *words*, from one language into another, such liberties have been occasionally taken as were considered necessary to keep up the spirit of the original, without deviating from the sense of the author. How far the translator has succeeded in these respects is not in his province to decide; conscious that egotism is too partial to deserve approbation, he cheerfully submits his labours to the opinion of an impartial, liberal, and discerning public.

Saville Row, June 16, 1803.

THE

AUTHOR'S PREFACE.

THESE new Elements of Physiology, in which the doctrine I profess, and have for several years taught in public lectures, is concisely elucidated, are arranged by the model of the immortal Haller's small Physiology *(Primæ Lineæ Physiologiæ)*. Far be it from me to foster the pretension of having equalled a work which, to use the expression of a man of uncommon talents (Vicq-d'Azyr), changed the appearance of the science as soon as it was published, and united every voice. If these new Elements merit a preference, the honour of it is not due to their author, but to the age in which he wrote, being enriched with numerous facts and results from the improved state of the physical or philosophical sciences, which render Physiology quite a new study.

It will be easily perceived that the plan I have followed essentially differs from that which several learned physicians have adopted, and among others Professor Dumas, in his erudite Treatise, a part of which is already published. By uniting a great number of facts, by adding the fruits of my own observation and experience to those already known, and connecting them by a method that combines exactness with simplicity, I have endeavoured to hold a just medium between a conciseness bordering upon obscurity, and those works in which the authors, by entering into every detail, exhaust their subject, and seem to have written only for those who have sufficient time or inclination to investigate them.

If it should be objected that the enterprise I have undertaken is greater than becomes a person of my age, I shall answer, at the risk of maintaining a paradox, that young men are, perhaps, the most proper for the compilation of elementary works, because their memory retains with more correctness the difficulties they had met with in prosecuting the study, the tracts they had followed to surmount them, and a recent experience makes them acquainted with the defects and advantages of different methods; so that he who in the shortest space of time has acquired the greatest stock of solid information, will be in many respects, the most able to direct his successors in the thorny paths of instruction and knowledge.

> "To elucidate truth in the most perfect order, that in which it has been naturally found should be observed; for the best manner of instructing others is to conduct them by the route through which we must have passed to instruct ourselves. By this method we shall not have so much the appearance of demonstrating things already discovered, as of investigating and discovering new facts." *Condillac.*

As to the style in which this work is written, I have always sacrificed elegance to perspicuity, from a full conviction that the latter is a very principal merit in an elementary book. I have also endeavoured to observe the same order in the succession of objects, and to apply to the science of man the principle of the natural connexion of ideas, which is so well described by Condillac in his Treatise on the Art of Writing, to which principle this philosopher has proved that all the rules of the art may be traced. Notwithstanding the rigid exactness I was determined to follow, I considered myself at liberty occasionally to make use of metaphorical expressions, according to the example of the ancients, of Bordeu, and several other physicians and physiologists not less celebrated among the moderns; because, if conciseness does not consist in the art of diminishing the number of words, it has a less relation to the privation of images, which sentiment is extremely well expressed by a lady of the present day, who is the greatest honour to her sex. " The conciseness that is truly enviable is such as was employed by Tacitus, which is both eloquent and full of energy; and images are so far from injuring this justly admired brevity of style, that figurative expressions retrace the greatest number of thoughts with the smallest number of terms." *De la Litterature, considerée dans ses Rapports avec les Institutions sociales*, par Madame de Staël Holstein, tom. ii.

Those who are predisposed to see nothing but romance in Physiology, and not the history of the animal economy, will, doubtless, reproach me for not having taken notice of a great number of absurd or ingenious hypotheses on the use of various organs; for example, of having omitted mentioning the opinion of the spleen being the seat of laughter and gaiety: the sentiments of authors who considered it a counterpoise to the liver, in order to maintain an equilibrium of the *hypochondria*, and even the opinion of the ancients, who thought it was the secretory organ of the black bile (*atrabilis*), &c. Would it not be losing important time in useless discussions? and, as Bacon observes, to give rise to the art of making a thousand questions from one only, by answers that are always less satisfactory, if we were to bring forward similar errors in order to refute them? I have purposely omitted this unnecessary display of information, from a persuasion that good works are as much distinguished by the omission of some things, as by the insertion of others.

One of the greatest defects in treatises on Physiology is the continual repetition of the same circumstances; an error which must be undoubtedly attributed to the difficulty of precise distinctions, when speaking of actions that depend on each other, which are often mutually connected, and performed in the animal economy.

" In composing a work we should avoid long periods, because they fatigue the mind; digressions, because they alienate it from the subject; too frequent divisions and subdivisions, because they embarrass it; and repetitions, because they tire the reader: a thing once said in its proper place is clearer than if frequently repeated elsewhere." (Condillac, *Essai sur l'Origine des Connoissances humaines*, 2 partie, sect. ii. chap. 4.) By following these precepts, which cannot be reflected on too much, an author, it is true, exposes himself to be considered superficial by those who read superficially, and speak their opinion from a single chapter; but he is amply rewarded by those who wish completely to understand a book before they pass their judgment on its merits.

After having pointed out the manner in which this work is written, I shall terminate an account of the motives that have determined its publication, if, in addition to the utility that the science and those who wish to learn may acquire from it, I subjoin the equally powerful reason of that satisfaction which is obtained by him who divides his time between the cultivation and the arduous exercise of our art. In these too short moments, when abstracted from teaching and from practice, absorbed in thought during the silence of study and in the tranquillity of meditation, he contemplates with an eye of pity those who maintain a detested existence among the basest intrigues, and console themselves with innumerable cabals, suggested by a supercilious ignorance and jealous mediocrity.

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ELEMENTS

OF

PHYSIOLOGY

INTRODUCTION.

SECTION I.

THE VITAL POWERS, OR PROPERTIES.

FROM the most remote antiquity, many philosophers, astonished at the numerous differences that organized living bodies present, compared with inorganized, have admired in the first a principle of particular actions, a power that maintains the harmony of their functions, and directs them to one common end: the preservation of individuals and species. This plain and luminous doctrine has been handed down to us, with various modifications, in different ages; and no person, at present, doubts the existence of a principle of life, which reduces those beings that possess it, to an order of laws very different from those to which inanimate beings are subject. To this we may attribute, as a principal distinction, the power of preserving the body which it animates, from the absolute influence of chemical affinities (to which it would have so strong a tendency to assimilate, from the multiplicity of its elements), and the power of maintaining its own temperature to a degree nearly equal, whatever may be the variation of atmosphere. Its essential property is not to keep up the aggregation of constituent molecules, but to attract others, which, assimilating themselves to the organs they vivify, serve to replace those daily lost, or employed for the purposes of nourishment and growth.

The word vital principle, vital power, &c. does not signify a being existing alone and independently of the actions by which it manifests itself: it should only be employed as an abridged formula, that is used to signify the aggregation of those powers which animate living bodies, and distinguish them from inert matter. Therefore, in this introduction, when we make use of these or any other equivalent terms, it should be understood as if we said the *tout ensemble* of laws that influence the animal economy. This explanation is absolutely necessary, since many authors, realizing the produce of abstracted ideas, have spoken of the vital principle as something quite distinct from the body, as a being perfectly separable, to which they have attributed a kind of seeing and perceiving, and even endued it with reasonable faculties.

All the phenomena which the observation of a human living body presents, could be advanced in proof of the principle that animates it. The changes of aliments by the digestive organs; the absorption of their nutritive parts by the lacteals; the circulation of these juices in the sanguineous system; the changes they suffer in passing through the lungs and secreting glands; the impressibility by external objects, the power of approaching or avoiding them; in fact, all the functions exercised in the animal economy manifestly declare its existence; but we are accustomed to draw a more direct proof from certain properties possessed by those organs by which these functions are performed. These properties are two; namely, *sensibility*, or the faculty these organs have of feeling; the aptitude they possess of perceiving, by the contact of an extraneous body, an impression, more or less powerful, which changes the order of their motions, accelerates or retards, suppresses or completes them; and *contractility*, a power, by means of which, parts irritated by the presence of a stimulus, contract, are thrown into action, and perform their motions. We shall separately examine each of these properties.

Sensibility.

The sensibility generally diffused in our organs does not exist in all to the same degree. In some it is obscure and scarcely apparent, and seems reduced to a degree absolutely indispensable for the fluids present to determine the action necessary to the functions they ought to perform. It should seem that no part of the body can do without this kind of sensibility absolutely necessary for life. Without it, how could various organs act upon the blood, to draw from it the means of their nutrition or materials for the different secretions? Therefore this degree of sensibility is common to every thing that has life, to animals and vegetables, to a man when asleep and awake, to the fœtus and the infant, to the organs of assimilating functions, and to those which put us on a level with surrounding beings. It is inseparable from a contractility equally obscure, but necessary for the circulation of the blood, the passage of humours, and, in fact, for all the phenomena of nutrition. (See the Synoptic Table of the principal Characters of vital Power, by Professor Chaussier.)

This low degree of sensation could not have been sufficient for the existence of man, and of beings resembling him, exposed to numerous connexions with every thing that surrounds them; therefore they possess a sensibility far superior, by which the impressions affecting certain organs are perceived, judged, compared, &c. This sort of sensibility would be more properly called *perceptibility*, or the faculty of judging of the emotions experienced. It requires a centre, to which the impressions have a mutual relation; therefore it only exists in animals, which, like man, have a brain, or something equivalent in its place; whilst zoophytes and vegetables, not possessing this central organ, are both destitute of this faculty: however, polypi, and several plants, as the sensitive, have certain spontaneous motions, which seem to indicate the existence of volition, and consequently of perceptibility; but these actions, like that of a muscle from the thigh of a frog excited by the galvanic stimulus, are occasioned by an impression, that does not extend beyond the part itself, and in which sensibility and contractility exist in a confused state.

Sensibility, to a certain degree latent in particular parts of the body, cannot be exactly compared to that of vegetables, since these organs, generally possessing such a small share of sensibility in a state of health, have an increased or *percipient* degree of sensibility when in a state of disease, which is known by the presence of such severe pains, that it changes the stimulus to which they are accustomed, to produce this effect. Thus the stomach, on the coats of which the food produces no *perceptible* effect in its ordinary state, transmits very distinct sensations, and becomes the seat of most excruciating pains, when a few grains of a poisonous substance are mixed with it. In the same manner we are not sensible of the impressions made on the bladder or rectum by the presence of urine or fæces, until they have become, by accumulation, sufficiently irritating to stimulate these receptacles, and rouse their sensibility and irritability; which sensibility, before obscure, now becomes apparent. Should it not be suspected, that if we have not a consciousness of impressions made upon our organs by the fluids contained in them during health, it is from our being accustomed to the sensations they excite almost uninterruptedly, of which we have only a confused perception that terminates imperceptibly? And may we not be permitted, in this point of view, to compare these organs to those in which reside the senses of vision, hearing, smell, taste, and feeling, which can no longer be excited by habitual stimuli, to which they have long been accustomed?

The parts of the human body that have the least sensibility, are, in general, those of firmer texture, and which receive a smaller number of nerves, such as bones, ligaments, tendons, and membranes: yet we cannot coincide with Haller that these parts are insensible, since they manifest, when diseased, most exquisite feeling; and this cannot be justly attributed to a rarefaction of their structure taking off compression from nerves, since by such swelling they ought to become, on the contrary, more compressed; but to the introduction of a greater degree of vital energy in their substance by the morbid affection, as we shall see hereafter in treating of inflammation considered physiologically. We should not altogether attribute sensibility of parts in proportion to their consistency, since the skin is more sensible than cellular membrane, and by far inferior in density.

Nothing in the living body is absolutely insensible, except the cuticle and parts depending on it, as the nails and hair; but in each organ sensibility is found so modified, that it is not affected by the same stimuli. Thus the eye is insensible to sounds, as the ear is to light. A solution of the tartar emetic, applied to the conjunctive membrane of the eye, produces no disagreeable impression; but carried into the stomach, it excites convulsive motions: whilst the acid of the latter irritates the membrane uniting the eyelids to the globe of the eye, and produces a violent ophthalmia. It is on the same principles that purgatives pass through the stomach without producing their effect in that viscus, and excite the action of the intestinal canal; that cantharides have a specific effect on the bladder, mercury on the salivary glands, &c. The relative magnitude of nerves in infants and women does not so well explain their great sensibility, as the softness of all their parts. Nerves, in fact, are smaller in men than in quadrupeds, in which they are employed for muscular actions, and seem rather to supply the function of nerves of motion than of nerves of sensation.

Indeed we ought carefully to distinguish sensibility from sensation. The first is only a faculty; the other, on the contrary, is a function. The former consists in an aptitude to be excited, impressed; the latter may be defined to be the impression itself that we experience from the contact of some body. (See the chapter on Sensations.)

Contractility.

Like sensibility, with which it is often so confounded that it is difficult to distinguish them, contractility is not uniformly distributed over every part of the body, but graduated and modified in each. Thus in cellular membrane, lymphatic glands and vessels, it is discovered by a slow, involuntary, and gradual contraction, whilst in muscles it appears in evident contractions, by rapid oscillations, with swelling, induration, and contraction of these organs. One of these species of contractility is known by the name of *tonic power*, or *tone;* the other is called *Hallerian irritability,* or musculosity, because it is an attribute of the muscular fibre. These two modes are visibly but two modifications of one and the same property. Sometimes the skin, particularly that covering the scrotum, throws itself, from cold, into alternate contractions and dilatations, which has a greater resemblance to musculosity, than that slow, gradual, and tonic-like action of the bladder on expelling urine. The most remarkable difference between these two kinds of contractility is, that one of them, at least in the generality of muscles, is subject to the power of volition, whilst the other is completely involuntary. The latter is similar to vegetative sensibility common to plants and animals, whilst musculosity is necessarily subservient to percipient sensibility, since the will that directs it absolutely requires for a modification of sensation, the existence of a centre, to which impressions are carried, and from which every kind of judgment emanates, &c. Thus there is no part without a manner of perceiving peculiar to itself; thus also there is no part but what acts, moves, and contracts, agreeably to its own manner; and parts that have been considered destitute of this motion analogous to muscular irritability, have remained in a state of immobility only from the want of an exciting cause conformable to their own particular nature. A more detailed account of contractility will be found in the chapters on Motion, Respiration, and Circulation of the Blood.

The following observation proves what credit should be given to the many experiments, by means of which Haller and his numerous pupils have endeavoured to exclude the greater number of our organs from the attributes of sensation and contraction. I lately assisted at an operation to extirpate the testicle for hydro-sarcocele, by C. Boyer. The tumour, when laid bare, by a dissection of the tunica vaginalis, was intrusted to my care during the division of the spermatic chord. This sac, filled with water, moved itself in my hand; its oscillatory contractions and the undulations of liquid were visible, and perceived by several assistants present at the operation. This fact, in my opinion, serves to prove, much better than all experiments made on living animals (the result of which experiments ought not to be applied to the animal economy of man with such confidence as is usually given to them), what we ought to think of the pretensions of Haller and his followers on the insensibility and non-irritability of serous membranes and other organs of analogous structure.

It is not our intention here to speak of porosity, divisibility, elasticity, and other properties that living bodies possess equally with inanimate substances. These properties never exert themselves to their greatest extent, in all their purity, if we may use the term; their result is uniformly altered by the influence of the vital powers: these constantly modify the effects, which seem to have a more immediate dependence on a physical, mechanical, or chemical cause, or some other similar agent. It is not exactly the same with respect to extensibility really vital, which is evident in certain organs, as the penis and clitoris: these swell and dilate by the afflux of humours when they are irritated; but this effect does not depend on a property peculiar, and distinct from sensibility and contractility. These parts dilate, their substance distends by the exercise of these powers, which would induce a like effect in every part that consisted of a similar structure.

It is the same with caloricity *(caloricité)*, or that power inherent in all living beings to maintain the same degree of heat under the greatest variety of surrounding temperature; a property, which enables the human body at the temperature of from 30 to 34 degrees of Reaumur to preserve the same in the frozen climate of the polar regions as in the atmosphere of the torrid zone. It is in consequence of the sensibility and irritability, it is by the functions to which these vital powers relate, that the body resists the equally destructive influence of excessive cold and heat.

The experiments of Blagden and Fordyce, in England, the observations of Duhamel and Tillet, in France, prove that the human body can support a degree of heat that will torrefy inanimate animal substances. The members of the Academy of Sciences were witnesses to several girls going into an oven, in which fruit and butcher's meat were baked: Reaumur's thermometer, that they took in with them, rose to 140 degrees; they remained there several minutes, without being incommoded. Transpiration is not the only mode by which nature throws off this excess of heat, since the evaporation of fluids does not prevent digestion of the food: besides, fish and frogs have been found to live and preserve their temperature in hot baths at a degree near ebullition. (See Sonnerat's Voyages in the East Indies.)

In fact, sensibility and contractility, which graduate and modify themselves into so many forms in different parts of the human body, are two inseparable faculties, if they are not identically one and the same, as in vegetables and animals not possessing a distinct nervous system.

It has long been considered, that if it were useful to distinguish them, to form the subject of deeper research, and better to discriminate all their phenomena, sensibility and contractility were, in effect, the same property. The school of Montpellier has maintained this point with the greatest firmness, and it daily acquires more partisans as well as increased probability.

> "Irritability is a wandering branch from the sensitive soul, that endeavours to regain a connexion with its trunk, from which it can no more be separated than an effect from its cause." (Fouquet, art. Sensibilité, Ancienne Encyclopédie.)

If it be useful to analyze in order to know a thing, it is equally advantageous not to multiply causes in mistaking the nature of effects; and if the multiplicity of phenomena that happen in living beings serve to admit a great number of causes that direct them, do not the constant harmony that exists in all their actions, their mutual connexions, their reciprocal dependence, prove the existence of one agent that presides over all these phenomena, and influences and directs them?

The hypothesis of the vital principle bears a relation to the philosophy of living bodies equal to attraction in astronomy. This science, to calculate the revolutions of stars, is obliged to admit of a force that constantly attracts them towards the sun, and only permits them to remove to a determinate distance, in describing their ellipses of greater or less extent round that common centre, which illumines them, and bestows light and heat on the important germs of life and fecundity. We are now going to speak of this power, to which all powers that animate each organ relate, and in which all the vital powers are blended, again reminding our reader only to take the term in a metaphorical and figurative sense: without this precaution, we must infallibly be led to those false reasonings, in which all have erred, who admitted that it had a real and separate existence.

The vital Power.

The vital power maintains a constant struggle with the powers to which inanimate bodies are subject. The laws of individual nature are, according to the observations of antiquity, in a continual conflict with those of universal nature; and life, which is only a prolonged combat, has entirely the advantage of the vital powers, when in a state of health; the issue of which is often uncertain in disease, and ceases the moment that the body which has possessed it enters the class of inorganic bodies. This constant opposition of vital laws to physical, mechanical, and chemical laws, does not prevent living bodies being subject to the influence of the latter. There are very evident physical, mechanical, and chemical effects taking place in the animated machine; and these effects are merely influenced, modified, and altered by the powers of life. When we are in an erect posture, why do not the fluids descend to the inferior parts of the body, agreeably to the laws of gravitation, which attract every body towards the centre of the earth? The vital power evidently opposes itself to this statico-hydraulic phenomenon, and counteracts this tendency of the fluids in proportion to the robust and vigorous state of the individual. If the person be reduced by former disease, this propensity will be imperfectly resisted; the feet in a certain time swell, and this œdematous swelling can only be attributed to the diminished energy of the vital powers that regulate the distribution of humours, &c.

The tumbler stands on his head; the blood does not go entirely to that part, although it now becomes the most depending: however, the natural tendency of the fluids towards the most inferior parts is not totally destroyed, but only diminished; for if he should continue a long time in the same position, the counteraction of hydraulic and vital powers would lose its equilibrium; the former would prevail, and the brain become the seat of a very dangerous congestion or accumulation of blood.

The following experiment incontestibly proves what we have just remarked on the force of resistance, which in the living human body serves to counterpoise, with more or less success, the influence of physical laws. I applied bags filled with very hot sand all along the leg and foot of a man who had just been under the operation for popliteal aneurism. The artery was tied in two places under the ham. Not only was the usual coldness, that follows an interruption to the course of the blood, prevented from coming on, but the extremity thus managed acquired a degree of heat much above the ordinary temperature of the body. The same apparatus applied to a healthy limb was unable to produce that excess of caloric, doubtless because the member is possessed of the energy of life to its utmost extent, and the vital powers opposed their influence to this effect.

The principle of life seems to act with more energy in proportion as the sphere of its activity is circumscribed; which induced Pliny to say that it was chiefly in the smallest things that nature had developed all her force and power: *Nusquam magis quam in minimis tota est natura.* (Histor. Nat. lib. ii. cap. 2.) I have, as well as many others, constantly observed that the body acquires an increase of vigour after the amputation of a limb. After the removal of a part of the body, we often see a manifest change take place in the constitution of individuals; persons of a feeble habit even anterior to the disease that occasioned the necessity of amputation, becoming robust; chronic affections from debility, such as scrofula and the like, disappear, and glandular swellings resolve; which indicate a remarkable increase of action in all the organs.

The extraordinary exercise of an organ is never made but at the expense of neighbouring parts by abstracting their fluids. Aristotle observes that the inferior extremities of those who are of hot temperament, or who greatly employ the organs of generation, are mostly dry and slender. Hippocrates mentions in his work De Aere, Locis, et Aquis (Foesius, fol. 293,) that the Scythian women used to burn the right breast, in order that the arm on that side should acquire an increase of size and strength. Galen speaks of the *athletes* of his time restraining their sexual organs to a state of complete inaction; so that, when thus shrivelled and debilitated to a great degree, by this repose they might not alienate nutrition, which would be entirely employed for the increase of muscular action. A young man, who had several times won the race in public games, abstained from venery for several months, before he entered the lists, quite certain of victory when he had determined to keep this resolution.

The parts most distant from the centre of circulation possess, in general, less vitality than those that are nearer.

Wounds of the legs and feet are most liable to become ulcerated, because, independently of the circulation of the humours, which the least increase of weakness renders more difficult, the life of those parts is in too low a degree for wounds to pass rapidly through their stages, and acquire a speedy cicatrization. The toes become frozen first when we remain too long exposed to intense cold; it is likewise in them that gangrene begins, which comes on sometimes in limbs after making ligatures on their vessels.

Thus, although we can say that the principle of life is not wanting in any part of our system; that no part exclusively possesses it; that it animates every individual living particle, each organ and system of organs; that it invests them with different properties, and in some measure, assigns them specific characters; it must however be confessed that there are some parts of the body furnished with it to a greater degree, from which all the others seem to derive the motion of life. It is observed that these central organs, these *foci* of vitality, to the existence of which the preservation of the body is intimately connected, are less numerous in proportion as animals are less different from man, whilst their number increases as life expands itself more equally; that these phenomena have a less immediate and necessary dependence, in proportion as we descend in the scale of beings; passing from animals of warm red blood to those of cold red blood; from these to fish, shell-fish, worms, insects, and then to polypi, which form the last ring in the chain of animals; and finally to vegetables, many of which, as the zoophytes, which resemble them in so many respects, possess a singular property of reproduction by detached slips; which presumes that each part contains the assemblage of organs necessary to life, and can exist individually. I was witness to a curious fact, which serves to support what I advance. A vine attached to the eastern wall of a forge sent off some of its branches to the inside of the wall: these branches, which only penetrated through some small air-holes, were covered with leaves in the coldest season of winter: this partial, premature vegetation went through all its periods, and was in flower when the remainder of the vine on the outside was beginning to bud, agreeably to the order of seasons, early in the spring.

Vegetable life, compared in its resources and effects with animal life, would throw very great light on several phenomena, which, at present, it is difficult for us to conceive and to explain.

The medical treatment of vegetables, which would be equally benefited by these researches, is almost entirely surgical. When the gardener lops off an over-luxuriant branch, to render vegetation more prolific; when the countrymen of Cevennes, as Chaptal observed, burn the inside of their chesnut-trees to stop the progress of a *caries* that destroys them; when the actual cautery is applied to ulcers truly fungous and foul in several trees, &c. it is on the organs of interior or assimilating life which vegetables only possess, that surgery is exercised; whilst, on the contrary, in man and animals it is chiefly confined to a derangement of the external organs. I shall conclude this note, already too long, with an observation on the wounds of vegetables. These, like those of the human body, are much less dangerous when their surface is smooth, than when their edges are rough, lacerated, or contused. Trees cut down with a saw, bud with difficulty, whilst those felled with an ax vegetate more briskly: The saw tears the vegetable structure, and produces a greater or less alteration in organization. The unequal surface of a tree thus cut down retains humidity, as destructive to the trunk, of which it induces a rottenness, as too great a quantity of pus, that so habitually moistens the surface of a wound, destroys granulation and prevents cicatrization.

The vital principle has been clearly distinguished by some, but others have confounded it with the rational soul, to which divine gift, as well as to the perfection of his organization, man owes his superiority over other animals. We admit this distinction, without knowing the nature of the connexion that unites the material principle, which receives impressions, and transmits them to the sensorium, which perceives them, examines, compares, judges, and reasons on them. Hippocrates established it on this luminous observation: if man consisted only of the material principle; if this made up all his existence, pleasure and pain would be to him as non-existing; he would have no sensations; for how could he account to himself for impressions produced?

The refusal to admit this distinction leads us to materialism; a very distressing doctrine, since it excludes the idea of an eternal Being, who dispenses rewards and punishments to that which survives our mortality. Here the province of physiology terminates, and metaphysics begin. Let us avoid entering on these obscure matters; the flambeau of observation would not throw sufficient light on the subject to dissipate the thick clouds in which it is enveloped.

Vital power is nothing but *natura medicatrix*, more powerful in the cure of a great number of diseases than the physician, whose only art often consists in rousing an action, or directing its exercise. A thorn is thrust into a sensible part; a severe pain is felt; the fluids flow from all parts; the affected part becomes red and swollen; all the vital properties are increased; there is the most exquisite sensibility, the greatest contractility, and the temperature is considerably raised: this augmentation of life introduced into the wounded part, this apparatus that arranges itself around the extraneous body, and the powers that develop themselves to occasion its expulsion, do they not indicate the existence of a conservative principle constantly presiding over the harmony of the functions, and unremittingly combating those powers that have a tendency to disturb the regular exercise of them, and to destroy vital motion?

Theory of Inflammation.

Inflammation, in my opinion, may be defined, *an augmentation of all the vital powers of that part which is the seat of it.* Sensibility there becomes more lively, mobility greater; and from this increase of sensibility and motion arise all the symptoms that denote the inflammatory state: thus pain, swelling, redness, heat, and the change of secretions, indicate a more energetic and active life in the inflamed part.

Every part of the human body, except the cuticle and its different appendages, the hair and nails, seems susceptible of the inflammatory state: we might add to these, certain dry and thin tendons, as those belonging to the flexor muscles of the fingers, which being pricked, and irritated in a great variety of ways, occasion no pain, and remain untouched in a whitlow, that induces suppuration in all the surrounding soft parts; and after suffering the contact of air, it exfoliates, instead of producing fungus. In all these parts the organization is in such a low degree, life so weak and languid, that they remain insensible to the impression of all the causes that tend to increase its activity.

The degree of sensibility of a part, the number and size of nerves and vessels that are distributed on it, proportion its greater or less aptitude to inflame: thus bones and cartilages take on, with great difficulty, a state of inflammation. When one of these parts is laid bare, the first effect of irritation that it suffers is a softening of its substance: a bone exposed becomes cartilaginous, and softens by the absorption of phosphate of lime, that forms the laminæ of its structure; it is not until after this change that fungous excrescences arise, as may be easily seen by observing the extremity of bones sawed in amputation. This tardiness with which inflammation shows itself in hard parts, explains the reason why it is almost unnecessary to keep an exact juxtaposition of surfaces in a fracture till the twelfth or fifteenth day; we ought not, however, to defer applying the contentive bandage during that time, since it is always useful in the commencement to obviate pain and lacerations, which the splinters would certainly produce.

The blood flows from all sides toward the irritated and painful part, which swells and becomes more red by its presence. This tumefaction would be boundless, if, at the time the arteries increased their action and diameter, the veins and lymphatic vessels did not acquire a proportional energy, and become capable of relieving the part from the humours that the irritation continually determines to it. The irritable and contractile powers are therefore increased with sensibility; the circulation is more rapid in the inflamed part; the pulsation of capillary vessels is manifest; it is consequently warmer, because, in a given time, a greater quantity of arterial blood passes through its structure, from which is disengaged a more considerable quantity of caloric (LXV.), and the continued effects of pulmonary respiration are better marked than in any other organ.

It is not our intention to treat of the varieties that occur in inflammation, varieties which are chiefly determined by the structure of the part that it affects, by the vehemence and velocity of symptoms and effects that it can produce.

Is not the swelling of an inflamed part induced by the same mechanism as that belonging to parts susceptible of erection, as the *corpora cavernosa* of the penis and clitoris, the nipple, the iris, &c.? In erection of the penis, as in inflammation, there is irritation, afflux of humours to the part, increase of sensibility and motion: yet it is not a state of inflammation. Nature had so disposed the organization of these parts as to permit them, with impunity, to experience this sudden augmentation of vital energy, necessary for the execution of those functions for which the organs they belong to are destined; and like inflammation, these swellings subside when the irritating cause ceases to act. Thus the pupil dilates, because the iris returns to itself, when the eye is no longer exposed to the rays of very strong light. The penis falls into its usual state of softness and flaccidity when no irritation solicits the presence of humours which remain during erection, and easily explains itself by the continuance of irritation without the necessity of having recourse to mechanical explanations to account for this phenomenon. When the irritation producing a vital turgescence of the penis, or of the iris, is carried too far, or continued too long, the natural distention becomes morbid. It is well known that priapism frequently induces gangrenous inflammation of the penis, and that a long-continued action of light on the ball of the eye brings on general ophthalmia.

The preceding considerations on inflammation prove that it is necessary to study the phenomena of this disease, even in a physiological point of view. The vital motions that in certain organs are performed so obscurely as to be imperceptible, acquire, by the inflammatory state, such a character of promptitude and intensity, that they become more easily known and distinguished. If taken in a general and abstracted point of view, only with relation to its object, inflammation can be adduced as a method that nature employs to parry the attacks of offensive agents; to which, when introduced into the body, or applied to its surface, she can only oppose a better marked development of those powers by which she is animated.

During the severe winter of 1793, Pelletier the chemist, in repeating the experiment for the congelation of mercury, obtained a solid piece in the ball of a barometer that he had long kept covered with ice, and continually moistened with nitrous acid. When the solidity of the metal was perfect, he took it out and put it on his hand; the warmth of the part, and temperature of the atmosphere, soon caused the mercury to pass into a state of fluidity: at the same instant he experienced such an insupportable coldness in the part, that he was obliged to throw off the mercury precipitately: a phlegmonous inflammation quickly came on the part, which was cold and painful, but terminated by resolution. Mercury made solid is one of the coldest bodies in nature. How rapid must the disengagement of caloric have been in this case, and how very deep must have been the impression felt by the palm of the hand, doubly afflicted by this physical effect and by vital reaction, the result of which was inflammation?

Analogous facts, carefully considered, should induce the *sectatores* of Brown to adopt for the effects of cold the distinction made by him between direct and indirect debility; they would be easily convinced, that, in its medical application, this negative existence of heat directly debilitating may, notwithstanding, from the reaction it occasions, be considered an indirect tonic.

The differences between organized and inorganized Bodies.

Philosophers have lately been much engaged in investigating the differences that exist between organized bodies and inanimate matter. It has been found that minerals were very distinct from vegetables and animals by the homogeneous nature of their substance, by the perfect independence of their *moleculæ;* each of which, as Professor Kant observed, possesses in itself the reason and manner of its existence by its unalterability, dependent on the simplicity of composition, and by being destitute of those peculiar powers that remove organized living bodies from the absolute government of physical laws.

The multiplicity and volatility of their elements; the necessary coexistence of liquids and solids; the nutrition and development by intussusception, whilst the increase of other bodies takes place by juxtaposition only; the origin by generation, and termination by death: such are the true characters that distinguish organized beings from inanimate substances.

The differences between Animals and Vegetables.

As to those circumstances by which vegetables differ from animals, they are much less decided, and consequently more difficult to be distinguished: there is, in fact, very little difference between a zoophyte and a vegetable; and the distance, as far as regards their interior economy, is greater between a man, who is in the highest scale of animal life, and a polypus, that is placed in the lowest, than between this animal and a plant. These fugitive gradations, however, can be taken, and a certain number of sufficiently marked differences established, to assign to vegetables characters that do not relate to individuals of the two other kingdoms. Their nature is more complicated than minerals, but less so than animals; the proportion of solids and fluids is greater than in the latter; therefore, after death, they long preserve the same form and size, although they become lighter. Their constituent principles are less diffusible. In fact, azot, the predominancy of which characterizes animal substances, is a gaseous and volatile production; whilst carbon, that forms the basis of vegetables, is a solid and fixed element. This circumstance, in conjunction with the small quantity of liquids, accounts for the long existence of dead vegetable matter.

Plants have been compared to animals in a profound sleep; it has even been said, that, to change them into perfect animals, it was only necessary to invest them with organs of sensation, powers of loco-motion, and voice. Notwithstanding this addition, the resemblance would be still far from exact; the vegetable would be deficient in digestive organs, which every animal possesses, from man to the polypus.

Vegetables have an origin, increase, and termination of life, the same as individuals of the animal kingdom, but have not, like the latter, the faculty of perceiving and moving at will: these two attributes particularly characterize *animate beings* or *animals;* they are essentially and mutually connected. Suppose a living being, possessing the organs of loco-motion, and destitute of sensations, surrounded by bodies that every instant threaten its feeble existence, and having no means of distinguishing those which are prejudicial, it would infallibly run into destruction. If sensibility, on the contrary, could exist independent of motion, how lamentably would those beings be situated: like the fabulous Hamadryades, which, immovably placed in the trees of our forests, support all violence offered to their rural habitation without being able to avoid it.

SECTION II.

ON THE RELATION OF PHYSIOLOGY TO SEVERAL OTHER SCIENCES.

IT would be forming a very erroneous idea of the mechanism of a living man, if we thought it consisted only in the application of physical laws to the phenomena of the animal economy, as some authors have maintained. Physiology does not exist on borrowed powers, but in a state of independence; it is an order of truths that peculiarly belong to itself, and which are elucidated in the observation of those acts, of which the succession and aggregation constitute life. It is enriched, certainly, by several facts from philosophy, chemistry, and calculation; but these are merely accessory, and do not essentially form the basis of the science. Thus, to gain a better knowledge of the mechanism of hearing and vision, elementary notions of sound and light are drawn from acoustics and optics; and to investigate, with greater accuracy, the nature of our solid and liquid parts, the manner in which animal substances incessantly pass from one to the other of these states, the assistance of chemistry is requisite. On the same principle, geometry and mechanics furnish the most advantageous forms for organs, and for the perfection of their structure.

No study is more truly interesting than that of the admirable relation existing between the conformation of our parts and the exterior objects to which they apply. These relative connexions are calculated with so much precision, established with such great justice, that the organs of the senses and of motion, considered in this point of view, are the most ingenious model that ever art has conceived and executed: so true is the sentiment of that great physician from *Pergamus*, that nature had done every thing before art, and even in a superior manner. *Quandoquidem natura, ut arbitror, et prior tempore sit, et in operibus magis sapiens quam ars.* (Galen de Usu Partium, lib. vii. cap. 13.)

It was by observing the means used by nature to prevent a diffusion of light in the eyeball, that Euler took a hint to improve his telescopes.

At the beginning of the last century, the geometrical physicians, seduced by the appearance of a rigorous precision, endeavoured to explain every thing by the diameter of vessels, their length and curvature, the compound reason of the action of solids and impetus of fluids. We shall see, in treating on different points of physiology, what defective theories were the result of these applications, and particularly of the force of action in the heart. All who followed the same tract ran counter to each other: yet we cannot reasonably doubt but that effects take place in the animated machine that relate to the laws of hydraulics. The brain, for example, has continual occasion to receive a great quantity of arterial blood, endued with an increase of vitality, by a recent passage through the substance of the lungs; but a too rapid afflux, a too sudden access of this fluid might change its structure. Nature, therefore, as we shall mention, in the circulation of blood in the brain has employed all the hydraulic means in her power to weaken the force of its access, and diminish the velocity of its passage.

Has man ever more happily applied the laws of hydraulics than nature has done in the construction of that surprising *rete mirabile* that the internal carotid arteries of quadrupeds form in the basis of the cerebrum? Without this disposition, the impetus of blood carried by the arteries with a force superior to that which animates the heart of man, and unable to overcome the resistance that is made by its own gravity, would have infallibly deranged the structure of this delicate organ.

As to the application of mathematical sciences and calculations, we must say, that few things being absolutely certain in physiology, and many barely probable, calculation can only be used on probabilities, and elements sought after in facts drawn from observation and experience; which facts, collected and multiplied to a certain degree, lead to conclusions that are equivalent to the most demonstrable truths.

This ought to be understood of the causes of phenomena only, and not of the phenomena themselves; for physiology is perhaps richer than any other science in certain facts easily proved by observation.

The phenomena that living bodies present, incessantly vary in their vehemence, intensity, and velocity. How is it possible to subject such variable elements to exact formulæ? I might as well put an expansible liquor, liable every instant to alter its volume, into a weak vessel hermetically sealed: yet the progressive motion of men and animals admits of calculations sufficiently exact; it can be advantageously employed to estimate the produce of our different secretions, the quantity of air or aliment introduced into our organs, &c.

We may reckon amongst the number of principal causes that have particularly retarded the progress of physiology, an error into which those have fallen who have endeavoured to explain all the phenomena that living bodies present to us by means of one science only, as chemistry, hydraulics, &c. whilst all these united cannot account for the whole of those phenomena; besides, the abuse that has been made of those sources of knowledge ought not to forbid their use. The information drawn from physics, chemistry, mechanics, and geometry, are so many means useful for the solution of the great problem of the living animal economy; a solution which ought not to be reckoned impossible, because it has not yet been made, and we shall approach still nearer to it in proportion to our attempts, when furnished with a greater number of given facts. But we cannot too often repeat, that he alone can justly pretend to that honour, who, in the application of physical laws to animated bodies, will duly consider the powers inherent in organized nature; powers that have a supreme influence over every action of life, and modify those effects which seem to have the greatest dependence on the laws that totally govern inorganized bodies.

Anatomy and physiology are united by such intimate connexions, that several have thought they were absolutely inseparable. If physiology, say they, have for its object a knowledge of the functions that our organs perform, how can their mechanism be understood if we be ignorant of the instruments that execute them? We might as well pretend to explain how the hand of a dial traces the circle of its diurnal revolution, if we were ignorant of the numerous springs and wheels that put it into motion. Haller is the first that established the union of anatomy and physiology, and who incorporated it in his great work: since Haller, a great number of anatomists, and amongst them *Sœmmering*, in a book lately published, *De Corporis humani Fabricâ*, has united both these sciences as far as possible; and in treating separately on each system of organs, he gives every thing that is known of their use and properties.

However intimate the connexions between anatomy and physiology may seem to be, they have appeared perfectly distinct to many; and we are in possession of several good works on anatomy, in which physiology occupies a very small place. The method of considering both the sciences together seems to offer the greatest advantages. In fact, if the mere description of our organs were sufficient for the physiologist who studies their functions, this point of view would furnish few observations really useful in the practice of surgical operations. To render the knowledge of the human body more particularly useful in the exercise of this art, it is not only necessary to consider its different parts separately, but also to take their aggregate result, and determine their relative connexion with exactness. The anatomist, who knows that the crural is the principal artery of the thigh, passing behind the knee, is continued under the name of popliteal, to go to the leg; that in its passage several branches are sent off to different parts of the limb; if he were ever so well acquainted with the name, the number of these branches, the varieties they may offer, the parts on which they are distributed, he would yet have a very insufficient knowledge of this branch of the arterial system, and what would be almost useless in the treatment of diseases to which it is subject: the situation of the artery, its direction, the parts that surround it, and their relative position, its situation being deeper or more superficial, &c. are the only circumstances that can be of any use to him.

The person who cultivates anatomy, in this point of view, is in the same situation as the chemist, who cannot form a clear knowledge of a substance until he can entirely decompose and recompose it, in all its parts; so the anatomist is not thoroughly acquainted with the human body, till, after having separately and carefully studied each organ, and each of the systems that a certain number of organs form, he can assign a proper place to each, determine the relation he observes, and the mutual proportionate connexion for the composition of our members. The study of the latter is even much longer and more difficult than that of the former; for the chemist who decomposes and reunites any known mixture, the posphate of lime, for example, only comes to a knowledge of the constituent principles of their respective proportions: the phenomena of situation completely escape his research. The anatomist, on the contrary, who knows that such a part is composed of bones, muscles, nerves, and vessels, ought not only to have a knowledge of each of these parts, and their proportionate size, but also the precise place they occupy.

Anatomy, studied in this manner, presents a widely extensive field; it is this art that Leibnitz called analysis of situation, *analysis sitûs*, and the knowledge of it is too important not to give it a distinct place in medical information. I do not wish to pass over in silence the motives adduced by teachers to unite anatomy and physiology. It is found that anatomy, when reduced to a simple description of organs, is too dry and tedious; physiology united makes it interesting, and gives variety: the attention of hearers is more certainly attracted, they listen with greater pleasure, and more easily retain what they have heard. Does it not seem that physiological disquisitions are to the auditors like honey on the rim of a vessel containing medicine to be given to a sick child, to disguise the bitterness of the liquor that is to restore its existence? In blending two objects, one of which presents to us no particular interest but its utility, whilst the other joins likewise attraction and amusement, the attention will not only be divided, but entirely disunited; and the minds of those who read or hear will pass lightly over dry detail, to seize with avidity that which is most engaging.

I think I have said enough to avoid reproach for having inserted in this book anatomical descriptions, which are to be found in a number of excellent treatises we possess on human anatomy; let us now examine the connexions that exist between physiology and comparative anatomy.

If we do not obtain a perfect knowledge of a machine till after having decomposed it into its most simple elements; if the mechanism of its action be not well understood until the separate operations of each of its different parts have been examined; comparative anatomy (by means of which we can study, in the great chain that animals constitute, the individual action of each organ, estimate its absolute or relative importance, and consider it as standing alone and reduced to its own power, to determine what part it has in the exercise of a function) is indispensable to those who wish to make very great progress in the knowledge of man; it may be considered as a kind of analytical method, through the medium of which we arrive at a more accurate knowledge of ourselves.

To obtain a just idea of the operations of the human understanding, and explain the generation of the faculties of the mind, metaphysicians have conceived a statue, that they have animated by degrees, successively investing it with the organs of our sensations. Nature has, in some measure, realized this vision of philosophy: there are animals that she has completely deprived of the organs of sight and hearing; in others, taste and smelling do not seem to exist independently of touch; in other instances nature has exercised this kind of analysis on a system of parts that serve for the exercise of the same function. It is thus that in some animals the organ of hearing, being destitute of those accessaries that serve to collect, transmit, and modify the rays of sound, is reduced to a simple cavity, full of a gelatinous liquor in which the extremities of the auditory nerve are suspended, and is exclusively proper to receive the impression of sounds; a fact which subverts all hypotheses that had attributed this sensation to other parts of the auditory apparatus.

Of all the natural sciences from which we can draw facts to enrich physiology, comparative anatomy is the most useful, which, like physiology, regards living organized beings; we have not, therefore, so much occasion to fear the fallacious applications that sciences so frequently furnish, which influence inanimate, inorganic beings, or which contemplate such as only possess in life what relates to the general properties of matter. Haller had so well estimated this utility of the introduction of comparative anatomy to physiology, that he has collected the greatest number of facts on the anatomy of animals known in his time, and placed them at the beginning of each chapter of his immortal work.

This consideration of living animated beings, so well adapted to develop the secret of our organization, has likewise this advantage, that it enlarges the sphere of ideas in those who follow it. Let any one who desires this vast extension of things so necessary to medicine, in which the facts are so numerous and various, the explanations so contradictory, and the rules of conduct so destitute of precision, take a general glance over this great division of organized beings, many of which, by their physical structure, so nearly resemble man, and he will find the supreme Architect of the universe distributing to all the element of life and activity; bestowing on some a greater, on others a less degree of motion; so that, all being formed on the same model, they should seem to be only so many shades, infinitely varied and insensibly graduated; like colours, never passing from one to the other abruptly, but rising or descending by small and regular gradations; having in the interval that separates two different beings, a great number of species that carry us from one to the other, and which offer a continued series of degradations or perfections; organization becoming more simple if we descend from man to inferior species, and, on the contrary, more complicated in ascending from animals to man, who is the most complex being that exists in nature, which ancient philosophy justly considered a masterpiece of the Creator.

It is a beautiful and grand idea to form the scale of beings, which, says Bonnet, connecting all worlds, embracing every sphere, extends itself from an atom to the highest cherubim, without beginning with atoms and finishing with cherubims, which would be commencing and terminating in darkness. If it be reduced to natural and well-known beings, that are subject to observation, we shall find that this idea is not so chimerical as several of the learned, whose authority is most respectable, have pretended. The plan, as traced by C. Bonnet, is visibly defective: beings are there found connected that have a very weak or illusive resemblance to each other. The present state of natural sciences would admit of a better arrangement; we could at least endeavour to effect for all bodies what Jussieu has done relative to vegetable productions; and if this undertaking, conducted by men capable of executing it, left any thing more to be desired, would not this necessary imperfection indicate the existence of other worlds, or parts still unknown to us, on the globe we inhabit, where minerals, vegetables, and animals might be found, the absence of which would form a vacuity in their immense and connected series? This idea is strengthened by the following circumstance:

The philosopher Kant, whose principles are in the greatest esteem in every northern country of Europe, in examining the celestial bodies, thought he saw, in the prodigious distance that separates Saturn and Jupiter, a space, in which another planet ought to be found. The conjecture is become a truth clearly demonstrated since the discovery of *Uranus* by Herschel: this astronomer publicly confessed that the logic of the German philosopher had conjectured that which his telescopes had enabled him to discover. *Demonstratum enim fuit et hoc nullam rem contrarias, vel omnino multum differentes qualitates recipere posse, nisi per media prius iter fecerit.* (Galen de Usu Partium, lib. iv. cap. 12.)

If the intimate structure of our organs conceal itself so tenaciously from our researches, it is because their constitutive parts, the most delicate and complete, are in such minute proportions, that our senses can have no hold of them; it is then useful to have recourse to analogy, and to study the organization of animals that furnish the same organs, constructed with greater relative proportions. It is thus that the cellular structure of the lungs, which cannot be clearly demonstrated in man, on account of the excessive tenuity of their smallest lobuli, evidently displays itself in the vesicular lungs of salamanders and frogs; in the same manner, the scales covering the bodies of fish and reptiles, or the claws of birds, give us a just idea of the structure of the epidermis, and of the disposition of its small laminæ that are covered over each other on a part of their surface, &c.

The human structure being mostly complicated, ought to produce more numerous effects, more varied results, and more difficult of comprehension: we do not follow the analytical method; we do not proceed from simple to compound, in beginning the study of animal organization with that of man. We should, perhaps, arrive more naturally and easily at the solution of the great and difficult problem of the animal economy, by beginning to explain its most simple terms, gradually rising from plants to vegetative animals, as polypi; from these to animals of white blood, then to fish and reptiles; from these to animals of warm blood; finally to man himself, placed at the summit of this long series of beings, of which the existence becomes complicated in proportion to their approximation to him.

The study of every part of natural history, and particularly of comparative anatomy, must be therefore of infinite advantage to the physiologist; a truth forcibly expressed by the eloquent Buffon (*Histoire Natur.* tom. v. 12mo. p. 241. *Discours sur la Nature des Animaux)*, when he said, if no animals existed, the nature of man would be still more incomprehensible. This truth will be more forcibly perceived, when physiologists are in possession of the whole of the lectures on comparative anatomy, by Professors Cuvier and Dumeril. (See the two first volumes already published.)

SECTION III.

CLASSIFICATION OF THE VITAL FUNCTIONS.

AFTER having separately treated of the vital powers or faculties, nothing is more easy than to distribute, in a clear and methodical order, those functions which the organs animating these faculties perform. The word *function* might be defined *means of existence:* this definition would be so much the more correct, as life is nothing but the exercise of these functions, and which ceases when some of the most important can no longer act. It is for want of having distinguished faculties from functions, which are only faculties or powers reduced to action, that several modern divisions, although far preferable to the ancient classification of functions into vital, animal, and natural, are still deficient in exactness and simplicity.

The best method of classing the actions that are performed in the human body is, doubtless, that which distributes and arranges them after the object they fulfil. Aristotle, Buffon, and particularly Grimaud, have established on this basis the outlines of a method that we shall adopt, with certain modifications about to be explained.

Aristotle and Buffon had observed, that, amongst the actions of the living economy, some were performed in all beings that have life, as animals and vegetables, both asleep and awake, &c. whilst others seemed the exclusive properties of man or animals bearing a greater or less resemblance to him. Of these two modes of existence, one vegetative, the other animal, the first appeared to them most essential, since it was more extensive, and consisted entirely in the assimilation of extraneous moleculæ, absolutely necessary to the preservation of the living being, which, by constantly losing its own substance, would soon cease to exist if these continual losses were not incessantly renewed by the act of nutrition. *Nam anima nutritiva etiam aliis inest, et prima et maxima, communis facultas animæ secundum quam omnibus vivere inest.* (Aristoteles de Anim. lib. ii. c. 4.)

Grimaud, professor of physiology in the university of Montpellier, too soon taken from a science, which he cultivated like a philosopher, truly worthy of the name, adopted this simple and luminous division, developed it better than had been done before his time, and constantly followed it in his lectures and his works.

In his manuscript lectures on physiology, compiled by himself, a voluminous work which I partly possess, he seems to exult in this division, that he had in some measure ascribed to himself by the successful arrangements he made, and the alterations he introduced. In every lecture, I might almost say in every page, he returns to this division: "The functions," says he, "may be divided into two great classes: some take place in the *internal parts* of the body, and have a mutual relation exclusively; the others are exercised on the *external parts* of the body, and have a relation to external objects, &c." The digestive faculty, according to him, presides over the *internal functions* that have for their object nutrition, and the power of loco-motion directs the *external functions.* "It is by the organs of sense that an animal increases its existence, maintains and diffuses it on surrounding objects, and forms a knowledge of the qualities by which those objects interest it; it is by means of the muscles, necessarily obedient to the organs of the senses, that it is connected with objects, and places or disposes itself agreeably to their mode of activity, &c."

This distinction of functions into *internal*, which he likewise calls *digestive*, and into *external* or *loco-motive*, is lately renewed by a young physician very much to be esteemed for other things, who calls the first *organic*, the second *animal* functions: the first of these denominations is entirely destitute of exactitude and correctness, since it leads to a belief that animal or relative life is not dependent on organs, and that these vital instruments are only employed to internal life or nutrition (*Motus assimilationis*, Bacon.—*Blas alli-rativum*, Van Helmont.) This distinction, I affirm, does not comprehend the whole of the phenomena; it does not include the *tout ensemble* of functions that are carried on in the animal economy. In fact, we do not find in either of those classes, the act by which animals and vegetables reproduce themselves, and perpetuate the duration of their own species. All these *conservative* functions of *species* have no place in such arrangment; it only treats of the conservative functions of individuals.

I have, therefore, thought it my duty to comprehend under two general classes, 1st, The functions that serve for the preservation of the individual, and render it capable of an isolated mode of existence; 2nd, The functions that serve for the preservation of the species, the absence of which would not prevent man from existing, as we see in eunuchs, but without which the human species would soon perish when deprived of the ability to reproduce itself. In establishing these two great divisions, I have only kept in view the object, the end that each class of functions ought to fulfil.

Among those that are employed for the preservation of the individual, some perform this office by assimilating the nutritious part of the aliment into its own peculiar nature; others, in establishing connexions with surrounding beings, agreeably to its own existence.

The functions that serve for the preservation of the species may also be divided into two orders. Those of the first require the intercourse of both sexes, and constitute generation, properly so called: those of the second exclusively belong to woman, who, after having conceived, is alone destined to support, nourish, bear, and suckle the new being, the produce of conception. (See the Table at the end of this Introduction.)

The internal functions, both assimilating and digestive, concur to fulfil the same end, and assist the formation of nutritive matter. Food, after having been received into the body, is subject to the action of the digestive organs, which separate its nutritive part; the absorbents receive and carry it into the mass of humours; the circulatory system conducts it through every part of the body, and towards all the organs. The lungs and secretory glands there add to it certain elements, and deprive it of several others, change, modify, and animalize it; in fact, nutrition may be considered as the complete performance of the assimilating functions, which have all one common object, the nourishment and growth of parts; nutrition supplies them with this animalized substance, assimilated by these successive actions.

Nevertheless, several of these functions serve, at the same time, to preserve and destroy: absorption carries extraneous moleculæ to be employed for the increase of organs, as well as those organic moleculæ that are separated by motion, friction, heat, and all other physical, chemical, and vital causes. The action of the heart and vessels pushes these (combined with parts truly excrementitious) towards the lungs (which combine the oxygen of the atmosphere with nutritive parts, as well as separate from the blood that which can no longer be employed for the nourishment of organs), and also propels them towards the secretory glands, which not only purify the liquid, in separating that part of it which cannot remain in the animal economy without danger, but also elaborate or prepare particular liquors: some of them, the produce of nutrition, serve for this purpose, and impress a certain degree of animalization on the subjects of its influence, the saliva and bile for example, while others seem to be intermediate states, through which nutritive matter is obliged to pass before its complete animalization, as serous liquors, and fat.

The external or relative functions, alike approximating by their result, form the connexion of the individual with that which surrounds it; sensations, by informing it of the presence of objects that may either assist or prejudice; motion, to approach towards, or recede from those objects in proportion as it may perceive a mutual agreement or disagreement, or as the opposite sensations of pleasure or of pain may result from its action on them, or their impression on it; lastly, the voice and speech cause it to communicate with beings that possess the same medium of communication without a change of situation. The brain is the principal organ of these functions, as the arterial system is the centre of assimilating functions. It is to the brain that all impressions which the organs of sense receive are carried; it is from this part that all judgment, all voluntary motion, and the voice, proceed; it is to the sanguineous system that all moleculæ are carried that are to serve for nutrition, and those which are to be removed from the body.

Every organized living body has, necessarily, assimilating functions; but as assimilation requires means more or less numerous and powerful, according to the nature of the being that exercises it, the chain of assimilating phenomena commences in vegetables by absorption, since it draws directly from the earth the liquor to be employed for its nourishment. Its absorbent system also performs the functions of a circulatory organ, or rather, circulation does not exist in plants, and we can only compare the direct and progressive motion of the sap, which ascends from the root towards the branches, and sometimes recedes from the branches towards the roots, to the circulatory course of fluids, which takes place in man and animals that most resemble him, by means of a system of vessels which every moment brings them back to the same cavities, and propels them through every part of the body, by forming an entire circle, often a double rotation, as in *animals of simple or double circulation*, that is, *of which the heart has one or two ventricles*. Vegetables respire in their own peculiar manner, and alter the atmospheric air by receiving the carbonic acid gas, the produce of combustion and respiration of animals; so that by a truly admirable reciprocity, vegetables that decompose the carbonic acid and exhale oxygen, continually purify the air, which is corrupted by combustion and animal respiration.

The conservative functions of the species are common to animals and vegetables; the organs to which they are intrusted, compared with the numerous individuals of the two kingdoms of nature, present a resemblance that has astonished all naturalists, and induced them to say, that of all the actions of vegetable life, none was more analogous to those performed in the human economy than that by which fecundation is effected.

We shall not here treat of the general characters of the two orders of functions that serve for the preservation of the individual; their marked differences are pointed out in several parts of this work, particularly in the articles of sleep and the fœtus (CXVI. and CLXVII.) We shall only remark, with all authors who have treated of them in a general manner, that they are always in an inverse relation to each other; so that in proportion as the assimilating functions increase in activity, so does the energy of exterior functions diminish.

Grimaud has given the most extensive development to this idea, of the constant opposition between these two series of actions, over which preside, according to the opinion of this physician, two powers, which he calls *loco-motive* and *digestive*. It is marked in no species of animals more than in the carnivorous, which connect senses abounding in stratagem, and muscles capable of extraordinary action, an assimilating power in so low a degree, that their aliment, in order to be conveniently digested, should possess a composition analogous to that of their organs.

> In carnivorous animals the digestive power is extremely weakened, but the muscles are very strong. This relative power of muscular organs was extremely necessary, since these animals were only to exist by plunder and carnage; that their instinct, in conformity with their organization, makes them in continual warfare with every living being, and cannot support themselves but by coming off victorious in those combats to which nature continually instigates them. (Grimaud, premier Mémoire sur la Nutrition.)

Too great importance ought not to be attached to this classification, which, like all other divisions, is entirely hypothetical. Every thing maintains itself, every thing is connected and mutually agreeable in the animal economy; the functions are reciprocally connected, they act together: the whole represents a circle, of which it is impossible to find the beginning or end (*in circulum abeunt*, Hippocrates). In man, when asleep, digestion, absorption, the circulation, respiration, the secretions, nutrition, sensations, motion, the voice, and even generation, can exert themselves at the same time: but any person that gave his attention to these simultaneous exertions, in order to obtain a knowledge of actions in the animal economy, would have but a very confused notion of them.

> The division I establish ought not to be taken in a rigorous sense, and as an absolute truth; it is a mere hypothesis, which it is only necessary to follow so far as it serves you to dispose of your ideas with greater order; for every arrangement, although arbitrary, is useful, insomuch as it submits to our reflection a great quantity of ideas, and consequently facilitates the comparison to be made of them. All the actions of nature are alike, they are so necessarily and intimately connected with each other, and nature passes from one to another by such uniform motions, by gradations so insensible and cautious, that there is no space to mark out lines of separation if we wished to trace them. All our methods, that distribute and class natural productions, are only abstractions of the mind, that does not consider things as they are in reality, but which attaches itself to certain qualities, and neglects or rejects all others. (Grimaud's Lectures on Physiology.)

In making ourselves familiar with these abstractions, we should soon take them for realities; we should go so far as to perceive two very distinct kinds of life in the same individual; we might then assign, as characters of internal life, the power of acting by means of organs independent of the influence of volition; although this faculty of the soul presides over the phenomena of respiration, mastication, the excretion of the urine and fæces, of being present in organs destitute of symmetry; although the heart, lungs, and kidneys present a most evident relative proportion; of existing in the fœtus, which neither respires nor digests, &c. yet nothing in the animal economy, said Galen, is subject to invariable laws, nor able to afford such exact and calculable results as can be expected from an inanimate machine. *Nil est in corpore viventi plane sincerum.* Galen.

SECTION IV.

THE SYSTEM OF THE GREAT SYMPATHETIC NERVES.

THE great sympathetic nerves should be considered as a medium destined to unite the organs that are animated by the assimilating powers, and by means of which man grows, develops himself, and constantly repairs the continual loss from vital motion. They form a nervous system, very distinct from the system of cerebral nerves; and as the latter are instruments of the functions by which we have a relation to external objects, so the great sympathetic nerves give motion and vitality to the internal, assimilating, or digestive functions.

Is not the nervous system of animals without vertebræ, that floats in the cavities with the viscera they supply, entirely confined to the great sympathetic nerves? It distributes itself chiefly on the organs of internal life, the activity of which seems to increase in animals, in proportion to the weakness of their external senses and power of loco-motion. If the great sympathetic nerves exist in all animals that have a distinct nervous system, do they not peculiarly contain the principle of this vegetative life, essential to the existence of every organized being, and to which belong the phenomena of digestion, absorption, the circulation, secretions, and of nutrition? Is it not, in fact, probable, that, in man, the system of the great sympathetic nerves has the most important influence in a great number of complaints; and that it is to its numerous ganglions that its affecting impressions have a relation, whilst the brain is, exclusively, the seat of intelligence and reflection?

These ideas on the use of the great sympathetic nerves are to be found in my Essay on the Connexion of Vitality with the Circulation. (See Mémoires de la Société Medicale, pour l'An 7.)

We cannot hesitate about resolving this question by an affirmative, if we pay attention to the origin, distribution, particular structure of these nerves, and to the acute sensibility that their branches possess, as well as to the disorders occasioned by an injury done to them.

These great nerves, extending the whole length of the spine, from the basis of the cranium to the inferior part of the sacrum, do not arise from branches received from the fifth and sixth pair of cerebral nerves on each side, but it may be said they acquire life and nourishment to the detriment of all the nerves of the spinal marrow, of which they receive the branches; and it cannot be said the great sympathetics arise from any of them exclusively. The numerous ganglions that are interspersed in their extent divide them into so many particular systems, from which nerves emanate, or are given off to the nearest organs. Among these swellings, which have been considered by physiologists as so many small *cerebra*, in which the preparation of that fluid, admitted by them to exist in the nerves, is carried on, no one is more important than the semilunar ganglion, situated behind the viscera that fill the epigastrium, from which arise those nerves that supply the generality of abdominal viscera. It is in the region occupied by this ganglion that all agreeable sensations are perceived, in which the great sympathetic nerves unite, that may be considered the centre of the system, formed by the whole of them. In sorrow, a sense of constriction is perceived that is vulgarly attributed to the heart: it is from this part, that, in distressing affections of the mind, painful influence seems to arise, which disturbs and deranges the exercise of all the functions.

See the centre of the epigastrium; Van Helmont mentions it under the name of *archeus;* Buffon, Bordeu, Barthez, and Lacaze, under the denomination of *centre phrénique*, because they attributed to the diaphragm what, in reality, belongs to those nervous ganglions that are situated before its crura.

The numerous filaments of the great sympathetic nerves are not so closely connected, nor of the same colour and consistence as the minute branches of cerebral nerves; therefore the preparation of them is more easy, the nervous fibrillæ are less distinct, their chords are tinged with red, more moist and abounding in juices; they likewise seem to be formed of a more homogeneous substance, membranous coverings form a smaller portion of them: they are also possessed of a more delicate and acute sensibility. It is well known how dangerous wounds of the mesentery are, which is a membranous duplicature, insensible in itself, but containing such a great quantity of nerves going to be distributed on the intestinal canal, that it is difficult for any instrument, however fine it may be, to pass through it without injuring some of their fibrillæ. The pain produced by an affection of the great sympathetics is quite of a particular nature; it has a direct tendency to destroy vital action: it is known that an affection of these nerves, from pressure of the testicles, suddenly destroys the power of the strongest man. Every one knows that patients who die from strangulated herniæ, a volvulus, or any affection of that kind, sink amidst the most excruciating agonies, finding a great depression, and tormented with continual vomitings. In all these injuries of the great sympathetics, the pulse is frequent and hard, a cold sweat covers the face, the features change, all the symptoms are alarming and rapidly fatal.

The system of the great sympathetic nerves is not only employed to establish a more intimate connexion between all the organs that perform assimilating functions; it also withdraws them from the influence of volition, which is such a variable faculty of the mind, that life would be in danger every instant, if it were in our power to stop or suspend the exercise of those functions to which existence is so essentially connected.

In fact, if we glance at the organs to which assimilating functions are intrusted, and which receive their nerves from the great sympathetics, their action, in the greatest number, is totally independent of the influence of volition.

All the parts that receive their nerves from ganglions, are equally independent of the will. Professor Chaussier thinks that the superior branches of the great sympathetics pass up by the side of the internal carotid artery, and go to the spheno-palatine and lenticular ganglions. Ribes also believes he has discovered, by dissection, that some long and very fine filaments follow the course of the branches of the cerebral carotid, and go with them to be distributed in the basis of the cerebrum, beyond which they cannot be followed. I have often remarked, in my own dissections, these filaments about the branches of the internal carotid, but always considered them of a cellular structure.

The heart, the stomach, the intestinal canal, &c. in not being subservient to it, seem to possess a more isolated and independent existence; they act and quiesce without our participation. Some of these organs, as the bladder, rectum, inspiratory muscles, which do not exclusively receive their nerves from the great sympathetics, are subject to the will, and receive the principle of their action from the brain: the first, in consequence of twigs sent off from the sacral pairs to the hypogastric plexus; the diaphragm, by the nerves it receives from the fifth and sixth pair of cervical nerves.

The great sympathetic nerves, therefore, only supply the diaphragm, rectum, and bladder, with sensitive nerves. This was very necessary; for if, like the heart and intestinal canal, these organs had received their nerves of motion from the great sympathetics, their action would have been independent of volition, like that of all parts which receive motion from them. The bladder and rectum, placed at one of the extremities of the digestive apparatus, and destined to receive the residuum of excrement from our solid and liquid food, would have continually emptied themselves in proportion as the matters had come into their cavities, destined to receive and retain them a certain time.

On the other hand, if the diaphragm had received its nerves of motion from the great sympathetics, respiration would have ceased to be a voluntary function, of which we can, at pleasure, accelerate or retard, and even entirely suspend the exercise.

> To prove that the act of respiration is subject to the government of volition, we can not only call in the assistance of analogy, and quote examples from reptiles, as lizards, frogs, serpents, salamanders, and toads, animals of cold blood, with whom this function is evidently voluntary, but also from slaves who, according to Galen, terminated their own existence, when obliged to appear in presence of the judges or executioners. Agreeably to the sentiments of this physiologist, and many others, it was by swallowing their tongue and inducing suffocation: but to see how unfounded this opinion must have been, it is only necessary to have a knowledge of the attachment of the muscles of this part, and the motions they permit.

The action of the brain would not then have been indispensably necessary to the preservation of life; and in an animal deprived of its brain, respiration would have been continued, and the circulation could not have been interrupted. The death of this viscus would not have suddenly induced a cessation of life in other parts, as it now occasions by preventing respiration, consequently the circulation of the blood and other relative functions.

The nerves that go from the spinal marrow to the diaphragm for its contraction (which contractile power is instantly lost if a ligature be made on them), seem to be the principal means that connect the internal, assimilating, or digestive functions with those that maintain an affinity of the individual to external objects: without this medium of union, the chain of vital phenomena would not have been so direct, and their dependence less necessary. Without this absolute necessity of the diaphragm to receive, by the phrenic nerves from the brain, its power of contraction, *acephali* that are born without this organ could have continued to live as they had done *in utero*, when the organs of vegetative life had received a blood, which had acquired modifications indispensable to life, in the lungs of the mother; but, after birth, when this connexion is destroyed, and reduced to the necessity of impregnating their own humours with the living principle contained in the atmosphere by respiration, they would be unable to obey this necessity, as the powers of respiration would be destitute of the principle that should stimulate them.

When an external inflammation has but little extent, and is situated in a part that has not many nerves, and its structure easily yields to the afflux of humours induced by irritation, the whole of the morbid derangements take place in the affected part, and the general order of functions is not sensibly altered; but if it be of considerable extent in a part possessed of very acute sensibility, or of a compact texture, as the fingers and toes, then fever arises, because the diseased part causes all the systems to participate in its action. This generalization of local affection is almost infallible in all cases where inflammation is internal in any organ of the assimilating functions: this effect may be reckoned constant, although Morgagni quotes several instances of inflammation of the liver, no symptom of which had indicated its existence.

> We know that innumerable little pustules, in the distinct small-pox, occasion only moderate fever but that it becomes violent, and even dangerous, if the disease be confluent; that is, if these small pustules are very near, and run into each other. Granulations of flesh, that arise in great numbers from an ulcerated surface, are so many little phlegmons, which do not produce fever; but if too much irritation cause them to unite, a fever will certainly succeed. Vaccination, in a great number of cases, is not followed by the least feverish symptoms, if attention be paid to make the punctures at a certain distance from each other, which is my constant practice, so that the inflammatory *areolæ* may not come into mutual contact.

A knowledge of the great sympathetics explains this difference: when an arterial part is attacked with inflammation, the irritation experienced must extend itself, by means of its nerves, to the brain, which, by a reaction, that Vicq-d'Azyr (who only develops the ideas of Van Helmont on this subject) calls internal nervous action, transmits this irritation to the heart, the organs of respiration, of digestion, and secretions, in which the phenomena that indicate the state of fever take place. When the heart, the lungs, or any other internal organ, on the contrary, is attacked by an acute inflammation, there is no necessity for an intervention of the brain to induce all the viscera to feel the derangement experienced by one of them; all are intimately connected by twigs sent from the great sympathetics, and keep up, by means of this nervous system that is peculiarly appropriated to them, a more intimate communication of sensations and affections. We may add, that the derangement of important functions by a diseased organ, indispensably induces proportionable changes in all the actions of the living economy, doubtless, in the same manner as a fault in only one wheel interrupts or deranges the mechanism of any machine.

I shall finish this introduction by saying a few words on the order adopted in the arrangement of chapters. I could have begun either by pointing out the external functions, or the assimilating, by sensations or digestion; yet I have given a priority to assimilating functions, because they are, of all others, the most essential to existence, and the exercise of them is never interrupted from the instant the embryo has existence until the time of death. In first beginning with their history, therefore, we imitate nature, who invests man with existence before she puts him in a state of relation with external objects, and does not deprive him of it until the organs of senses, motion, and voice, have finally ceased to act.

As to the arrangement of functions belonging to the same order, or concurring to the same end, it was too well traced by nature for me to mistake. I have thought it right to place the voice immediately before generation, that this disposition might indicate, at the first glance, the connexion existing between their phenomena. Several animals manifest their voice only during the time of salacity; birds that sing at all times, have, at this period, a stronger and more sonorous voice. When man becomes capable of reproducing himself, his organs suddenly develop themselves, as if nature wished to remind him that it is by means of the voice that he should express his desires to a being sensible of their influence and able to answer them: the voice, then, naturally serves as a passage between exterior functions and those that are employed for the preservation of the human species. And, lastly, I have joined an abridged history of life and death, to follow generation, in which is found every thing that did not belong to any of the preceding divisions.

The Plan of a new Classification of the Functions of Life.

CLASS I. FUNCTIONS THAT SERVE FOR THE PRESERVATION OF THE INDIVIDUAL. (Individual Life.)

- **ORDER I.** Functions which assimilate the aliment by which the body is nourished. (Assimilating, internal, or digestive functions.)
  - **GENUS I. DIGESTION** Extracts the nutritive part.
    - Reception of the food.
    - Mastication.
    - Solution by the saliva.
    - Deglutition.
    - Digestion in the stomach.
    - ——— duodenum.
    - ——— intestines.
    - Excretion of the fæces and of the urine.
  - **GENUS II. ABSORPTION** Carries it into the mass of humours.
    - Inhalation of chyle.
    - ——— lymph.
    - Action of vessels.
    - ——— glands.
    - ——— the thoracic duct.
  - **GENUS III. CIRCULATION** Propels it towards the organs.
    - Action of the heart.
    - ——— arteries.
    - ——— capillary vessels.
    - ——— veins.
  - **GENUS IV. RESPIRATION** Combines it with atmospheric oxygen.
    - Action of the parietes of the thorax.
    - ——— lungs.
    - Alteration of the air.
    - ——— in the blood.
    - Disengagement of animal heat.
  - **GENUS V. SECRETION** Causes it to pass through several modifications.
    - Exhalation.
    - Secretion by follicles.
    - ——— glands.
  - **GENUS VI. NUTRITION** Applies it to organs, to which it is to supply growth, and restore their loss.
    - Different in every part, according to the peculiar composition of each.
- **ORDER II.** Functions which form connexions with surrounding objects. (External or relative functions.)
  - **GENUS I. SENSATIONS** Inform the being of their presence.
    - Organs
      - The Sight.
      - Hearing.
      - Smell.
      - Taste.
      - Feeling.
    - Action of nerves.
    - ——— the brain.
    - Human understanding.
    - Sleep and watching.
    - Dreaming and sleep-walking.
    - Sympathy.
    - Habit.
  - **GENUS II. MOTIONS** Approach towards or remove it from them.
    - Organs and muscular motion.
    - The skeleton.
    - Articulations.
    - Place.
    - Progressive motions.
      - Walking.
      - Running.
      - Jumping.
      - Swimming.
      - Flying.
      - Creeping.
  - **GENUS III. THE VOICE AND SPEECH** Causes it to communicate with similar beings, without change of place.
    - The Voice.
      - Articulated, or Speech.
      - Modulated, or Singing.
    - Stammering.
    - Lisping.
    - Dumbness.
    - Ventriloquism.

CLASS II.
FUNCTIONS THAT SERVE FOR THE PRESERVATION OF THE SPECIES.
(Life of the species.)

- **ORDER I.** Functions which require the concurrence of both sexes, as
  - **CONCEPTION and GENERATION.**
    - General differences of the sexes.
    - Hermaphrodism.
    - Systems relative to generation.
- **ORDER II.** Functions which exclusively belong to females, as
  - **GESTATION.**
    - Of the uterus in a state of impregnation.
    - History of the embryo.
    - [illegible] and its membranes.
  - **DELIVERY.**
    - On the uterus after delivery.
    - The lochiæ.
  - **LACTATION.**
    - Action of the breasts.
    - Milk.

- **GROWTH.**
  - Infancy.—Dentition.—Ossification.
  - Puberty.—Menstruation.
  - Adolescence.
  - Youth.
- **VIRILITY.**
  - Temperaments.
    - Sanguine.
    - Muscular.
    - Biliary-melancholic.
    - Lymphatic.
    - Nervous.
  - Idiosyncracy.
  - Human race.
    - European Arab.
    - Negro.
    - Mongul.
    - Hyperborean.
- Decrease.
  - Age of decrease.
  - Old age.
  - Decrepitude.
- Death.
- Putrefaction.

Extraneous .. different

Heterogeneous .. opposite dissimilar in nature

diversity .. dissimilitude variety

destined .. to doom unalterably

Aqueous watery

Inanition emptiness of the body

Execrable .. hateful detestable

Authenticity, Authority genuineness

ELEMENTS

OF

PHYSIOLOGY.

CHAPTER I.

DIGESTION.

I. DIGESTION is a function common to all animals, by which extraneous substances introduced into their bodies, and become subject to the action of a particular system of organs, change their qualities, and furnish a new compound proper for their nourishment and growth.

General Considerations on the digestive Apparatus.

II. Animals only are invested with organs of digestion; every one, from man to the polypus, presents an alimentary cavity differently formed: the existence of a digestive apparatus, then, could be given as an essential character of animal life. In man, this consists of a long canal, extending from the mouth to the anus, into which open the excretory ducts of various glands situated in the vicinity, that secrete liquors, necessary to alter, liquefy, and animalize alimentary matter. The different parts of this digestive tube are not of an equal diameter. Wide at the beginning, formed by the mouth and pharynx, it becomes narrower in the œsophagus: this, in dilating, forms the stomach, which again contracts, and is continued down under the name of intestinal canal. The intestinal canal is of different dimensions in various parts of its extent, and it is principally from this diversity of magnitude that anatomists have established its divisions.

The length of the intestinal canal or digestive tube is five or six times that of an adult; it is comparatively more in a child: at this age, likewise, digestion is more active, proportioned to the necessity of the individual for growth and nourishment. The digestive cavity in man opens by two extremities; in some animals, the zoophytes, for example, one cavity executes both the functions of the mouth and anus; it serves for the entrance of aliments, and exit of their excrementitious residuum.

The extent of the digestive parts bears a relation to the nature of aliments by which animals nourish themselves. The less analogous these aliments are, by nature, to the substance of the animal they are to nourish, the longer they must remain in its body to undergo the necessary changes; therefore we observe that the intestine of herbivorous animals is very long, their stomach extremely large and often manifold, whilst the carnivorous have a short and straight digestive canal, so disposed, that animal substances which possess the most nourishment in the least bulk, the digestion of which, also, is more easy and expeditious, may pass through it with rapidity. In this respect man holds the medium between the species nourished by vegetables and those living on animals; he is therefore called, without distinction, to both kinds of nourishment; he is neither exclusively herbivorous nor carnivorous, but omnivorous, or *Polyphagous*. This question, so easy to resolve, has long engaged the attention of physicians, naturalists, and philosophers; each strengthened his opinion by plausible arguments, taken from the form and number of teeth, length of the intestinal canal, strength of its parietes, &c.

Solid and liquid Food.

III. The aliments by which man is nourished are selected from vegetables or animals: the mineral kingdom forms only *auxilia*, medicines or poisons. Mineral substances are of a nature too heterogeneous from that of man to be converted into our own substance; it should seem that their elements must be elaborated by vegetable life, which has justly given rise to the observation, that plants may be considered the elaboratory in which nature prepares the aliment for animals.

Whatever be the diversity of food, the action of our organs always separates the same nutritive principles from it: in fact, let the diet be totally vegetable, or entirely animal; the peculiar composition of our organs does not alter, an evident proof that the matter we extract from aliment to appropriate to ourselves is always alike: this is the explanation that ought to be given of the sentence of the father of medicine, *There is but one kind of nourishment, but many sorts of food exist.*

Although man, destined to live under all degrees of latitude, can make use of every kind of food, we observe that the inhabitants of hot climates generally prefer a vegetable diet. The Bramins, in India, the people of the Canary Islands, Brazils, &c. who live almost totally on herbage, grains, and roots, live in a climate, against the heat of which they are obliged to protect themselves: but the digestion of vegetables is accompanied with less irritation and heat. Aqueous, acidulous and cooling drinks are proper for hot climates; the people of the north, on the contrary, use more animal food, spirituous and fermented liquors. Drinks furnish much less nourishment than soft or solid food; perhaps they only assist digestion, as aqueous liquids, by facilitating the solution of solids, and serve as a vehicle for their divided parts, or as spirituous liquors, to stimulate organs and excite their action.

Hunger and Thirst.

IV. By these words, *hunger* and *thirst*, are understood two sensations that inform us of the necessity our body has of repairing its continual losses, occasioned by vital motion.

The effects of long abstinence are, the diminution of the weight of the body, perceptible in twenty-four hours; a falling away by a loss of fat; discolouration of the fluids, particularly of the blood; a loss of strength; great sensibility; loss of sleep; and painful sensations in the epigastric region.

Persons die of hunger more speedily in proportion to their youth and robust state. In this manner the unfortunate father, whose history is mentioned by *Le Dante*, when condemned to perish by inanition, and shut up with his children in a dark dungeon, was the last that died, on the eighth day, after having seen his sons, unfortunate victims of the most execrable vengeance ever remembered by man, sink amidst the convulsions of madness and the cries of despair. Haller has collected several instances of prolonged abstinence in his great work on Physiology. If we may give credit to the authors of these observations, many of whom are destitute of that degree of authenticity necessary for our confidence, individuals have been known to pass eighteen months, two, three, four, five, six, seven, and even ten years, without receiving any nourishment. We see, in the Memoirs of the Society at Edinburgh, the history of a woman who subsisted fifty years on whey only. The subjects of these observations are mostly weak, delicate women, living in obscurity, in a state of absolute inactivity, with whom life is almost extinguished, and evident only by a pulse nearly imperceptible, with a weak and slow respiration. It is a fact worthy of attention, that the muscles and viscera of some, opened after death, shone with a brilliancy evidently phosphoric. Would phosphorus be the product of the last degree of animalization? We can easily conceive, that, living in some measure on their own substance, the humours in these persons have been frequently subject to the action of animalizating and assimilating causes, which have made them pass under the greatest susceptible alteration.

Those who pretend that hunger depends on the friction of the surfaces of the stomach upon each other when empty, rely on the example of serpents, whose stomachs are purely membranous, and support it a long time; whilst the *gallinacei*, possessed of a strong muscular stomach, which contracts forcibly upon itself, bear it with difficulty. But besides the prodigious difference that exists between the vital activity in the organs of a bird and of a reptile, the stomach that returns on itself in proportion as it becomes empty, can contract so as to obliterate its dilatation, without the parietes, on that account, exciting any friction on which the sense of hunger should depend.

Those who think it is occasioned by an irritation on the diaphragm, effected by the spleen and liver when the stomach is empty, and does not support them, say, that it is instantly appeased by supporting the abdominal viscera with a large girdle; that hunger ceases as soon as the stomach is full, and before the food can have furnished any nutritive principle. In this hypothesis, entirely mechanical, how is the fact accounted for, that hunger is allayed for some time after we have passed the accustomed time of meals? Should it not rather be considered a nervous sensation existing in the stomach, that producing sensations, by sympathy, in every other part, inducing a strong excitement, kept up in the organ where it is situated, causes the humours to flow towards it from every part? This phenomenon, like all others that depend on nervous action, is subject to the laws of habitude, to the influence of sleep and passions of the mind, the dominion of which is so great, that we have seen literary men, deeply absorbed in meditation and thought, entirely forget that they had occasion for nourishment. Every thing that awakens the sensibility of the stomach, either in a direct or sympathetic manner, increases the appetite and excites hunger: thus *bulimia*, or canine appetite, sometimes depends on a continual irritation, from a tape-worm in the digestive organs. The impression of cold on the skin, by sympathetically increasing the action of the stomach, has sometimes produced this disease: Plutarch gives examples of it in the life of Brutus. Spirituous drinks and high-seasoned food provoke appetite, even although the stomach be immoderately full.

v. Thirst is still more violent than hunger, and less easily borne; the inspissation of the humours, deprived of the aqueous parts, which moderate their activity by perspiration, causes a general irritation, whence arises an acute fever with heat and dryness of the throat, which inflames, and may become gangrenous if the desire be not satisfied. The use of aqueous drinks is not the most certain way of allaying thirst. The traveller, exposed to the most scorching heat of summer, mixes spirits with common water, as the latter only would not sufficiently stimulate the mucous and salivary glands, the secretion of which lubricates the internal surface of the mouth and pharynx. Thirst increases whenever limpid secretions become more abundant; in this manner it torments the person labouring under *hydrophobia*, in whom the humours take a course towards the seat of this superabundance of fluid: it is excessive in *diabetes*, and in proportion to the quantity of urine.

Mastication of Food.

VI. The organs employed for the mastication of food are, the lips, the maxillæ or jaws, with their teeth, the muscles that perform their motion, and those constituting the parietes of the mouth. The motion of the lips is extremely varied, and depends on the simple or combined action of their muscles that cover the greater part of the face, and can be distinguished into the levators of the upper lip (levator anguli oris, levator labii superioris alæque nasi, levator labii superioris proprii); into depressors of the under lip (depressor anguli oris, depressor labii inferioris, levator labii inferioris); and into abductors (buccinator, zygomaticus major et minor, and platysma myoides). The action of the upper jaw has so little extent, that some have denied its existence, although it rises a little when the inferior is depressed; but it is chiefly by the depression of the latter, that opening the mouth is effected. The posterior muscles of the neck, and the mastoid belly of the digastric, effect a slight elevation of the upper jaw, which moves with the whole head, to the bones of which it is firmly united: in the act of mastication this part may be considered as an anvil on which a movable hammer acts, represented by the lower jaw; the latter falls by its own gravity when the levator muscles relax; the muscles of the os hyoides and the pterygoideus externus complete this motion, the centre of which is not in the articulation of the lower jaw with the os temporis, but answers to a line passing through its processes a little above the angles. It is round this axis that the lower jaw, in moving, performs rotation, by which the condyles are carried forwards, while the angles are directed backwards. Infants have the processes of the lower jaw less raised on the body of the bone; the direction of them and the centre of motion is always in the glenoid cavities, which the condyles never leave, however great may be the depression of the jaw. By this arrangement nature has obviated luxations, which would have been so frequent in the early ages of life, either by continued crying, in which these bones are immoderately depressed, or from a want of knowledge of a just proportion between the size of the mouth and the magnitude of bodies they might endeavour to introduce.

VII. The lower jaw forms a lever with a double angle, of the third kind, in which the power represented by the temporal muscles, the masseters, and internal pterygoid, is placed between the fulcrum and the resistance, at a greater or less distance from the chin.

The mode of articulation of the inferior maxillary with the temporal bones, only permits the motions of elevation and depression, in which the teeth, ranged in both the inferior and superior maxillæ, meet like the blades of a pair of scissars; and that lateral motion, occasioned by the round surfaces of the teeth gliding over each other, producing a friction, is extremely necessary to grind the food, to tear and divide its texture.

VIII. In carnivorous animals, or those that subsist on flesh, the levator muscles of the lower jaw, particularly the temporal and masseter muscles, possess a prodigious force proportioned to their size. In them the coronoid apophysis, into which the temporal muscle is inserted, is strongly marked; the condyle is received into a deep cavity; while, on the contrary, in herbivorous animals, or such as live on vegetables, the levator muscles are not so thick and weaker, but the *pterygoidei* stronger and better marked, by the action of which, lateral motion or grinding is effected. The glenoid cavities of the temporal bones are larger and shallower, and permit the condyles to glide easily on their surface. The respective or comparative powers of the levator and abductor muscles of the lower jaw, may be ascertained by examining the temporal and zygomatic fossæ: their depth is always in an inverse and relative proportion to the size of the muscles they contain. In carnivorous animals, the zygomatic arch, to which the masseter is attached, is depressed, and seems to have been indented by the strong power of this muscle upon it. In this point of view, man still keeps the medium between *carnivorous* and *herbivorous* animals; but nothing offers a better proof of his nature than the composition of the dental arches.

IX. The small, white, and very hard bones that form these arches, are not alike in all animals that possess them; every one of them has not, like man, three kinds of teeth. The *cuspidati* do not exist in the numerous species of chewing animals: some are deficient in the *incisores*. The first seem better adapted to divide substances of a fibrous texture that make considerable resistance; they are therefore very long and curved like pincers, the teeth of which intersect each other in carnivorous animals. The *molares* chiefly serve for the trituration of substances already separated by the *cuspidati*, or completely cut by the approximation of the *incisores*. These latter, to the number of four in each maxilla, acting only on bodies that offer but little resistance, are placed at the extremity of the maxillary lever: the molares are nearer to the fulcrum, therefore the greatest power of mastication is exercised by them. If we wish to break a very hard body, we place it, by instinct, between the last great molares; and greatly shortening the end of the lever by which resistance acts, we correct the lever of the third degree, which, although most used in the animal economy, is the most disadvantageous of all. The *cuspidati* have very long roots, so deeply fixed in the alveolar processes, as to bear, without danger of being pulled out, considerable force.

The enamel covering the external surface of the teeth, preserves the substance of the bone, exposed to the contact of air and destructive bodies, from the bad effects that this contact never fails to produce; and being much harder than the osseous substance, it enables them to break bodies that offer the greatest resistance, without any inconvenience: concentrated acids soften this substance, and produce a painful affection of the teeth; the sensibility of these bones resides in the mucous membrane that lines their internal cavity, on which are distributed the vessels and nerves that pass through the foramina of their roots. This membrane is the seat of a great number of diseases to which the teeth are subject. The enamel, constantly worn by friction, is susceptible of growth and restoration; the alveoli, in which the roots of the teeth are fixed, closely surround these roots, and the form of all of them being exactly conical, it is on every point of the internal surface of these cavities, and not at their bottom only, where the vessels and nerves enter, that the support is given. When, by accidental causes, or by advanced age, the teeth are fallen out, their alveoli close and become obliterated; the gums, a membranous red substance, dense and compact, which connects the teeth with the alveolar processes, become hard and callous on the margins. Old persons, after the entire loss of their teeth, have only an imperfect mastication; and this may be considered one of the causes of the slowness of their digestion, since the gastric juices dissolve with difficulty that food, the particles of which had not been sufficiently divided.

Salivary Dissolution.

x. This mechanical trituration is not the only change that aliments suffer in the mouth; whilst under the action of the masticatory organs that overcome the cohesion of their particles, they are, at the same time, penetrated by the saliva. This liquor, secreted by glands in the vicinity of the mouth, is poured in considerable quantities on the internal surface of that cavity, during the time of mastication.

The saliva is a transparent viscid liquid, formed of about four parts of water and one part of albumen, in which are dissolved phosphate of soda, of lime, and ammoniac, as well as a small quantity of muriate of soda: like all albuminous fluids, it lathers when agitated, by absorbing the oxygen of the atmosphere, to which it seems to have great affinity. Its attraction for this gaseous fluid is so considerable, that gold and silver may be oxyded, by triturating some very thin leaves of these metals with saliva.

The irritation occasioned by the presence or desire of food, stimulates the salivary glands, which swell, and become so many centres of afflux, to which the fluids are carried in abundance. Bordeu was the first that remarked how large a quantity of nerves and vessels were distributed on the parotid, sublingual, and submaxillary glands, from the external carotid, maxillary, and lingual arteries, and from the portio dura of the seventh pair of nerves, and the lingualis of the fifth, which either pass through their substance, or remain for some extent on their surface. This great number of nerves and vessels is in relative proportion to the quantity of saliva that can be secreted, which is considered to be about six ounces during the time of a meal; it flows in greater abundance when the food we are eating possesses more acrid and stimulating qualities. It forms an union with the mucus secreted by the glands of the maxillæ, cheeks, lips, palate, and tongue, with the serum exhaled by the arteries of the parietes of the mouth; moistens, penetrates, and dissolves the alimentary bolus, combines its divided particles, and impresses the first degree of alteration. There is no doubt but that the saliva, agitated with the food by the motion of the jaws, absorbs oxygen, and unites a certain quantity of this gas with the food necessary to assist the changes it must ultimately undergo.

XI. The muscular parietes of the mouth are in continual action during the time of mastication; the tongue presses the food on all sides, and thrusts it under the arched surface of the teeth; the muscles of the cheek, particularly the buccinator, against which the aliment is pushed, return it under the teeth to be sufficiently divided. When this division is effected, the saliva has completely penetrated it, and the tongue carries its extremity round the different parts of the mouth, and collects the food on its surface; when this collection is made, it presses the masticated bole against the arch of the palate, drawing the point upwards and backwards, at the same instant that the basis is depressed, and presents an inclined plane on which the tongue propels this accumulation of food from before backwards, to pass through the isthmus of the throat, and convey it into the pharynx. It is this passage of the food, and its descent through the whole length of the pharynx and œsophagus, that constitute deglutition, a function that requires the cooperation of several organs, the mechanism of which is rather complex.

Deglutition.

XII. To effect deglutition, the mouth closes by the approximation of both jaws; then the submaxillary muscles, digastric, genio-hyoideus, mylo-hyoideus, &c. elevate the larynx and pharynx, carrying the os hyoideus towards the lower jaw, made a fixed point by its levator muscles. At the same time the hyo-glossus elevates the os hyoides, it depresses and carries back the basis of the tongue; then the epiglottis, situated between these parts thus brought near each other, is pushed back and down by the base of the tongue that applies it to the aperture of the larynx. The accumulation of food pressed between the roof of the palate and superior surface of the tongue, slides on the inclined plane thus formed; and propelled by the point of the tongue turned backwards, it passes through the throat: the mucus secreted by the tonsils facilitates its passage. When the alimentary bolus has thus passed into the farther part of the mouth, the larynx, which had become raised and carried forwards, drawing with it the pharynx, now descends and falls backwards: the latter organ, stimulated by the presence of food, contracts, and would return some of it by the nostrils, were it not for the *velum pendulum palati*, drawn up by the action of the *levatores palati*, extended transversely by the *circumflexi palati*, carrying itself towards their posterior apertures, and apertures of the Eustachian tubes. Sometimes the resistance it offers is overcome, and some of the contents of the mouth is evacuated by the nostrils: this happens when we wish to speak or laugh while swallowing; the air then propelled with greater or less force from the lungs lifts up the epiglottis, and meeting the food, pushes it back towards those openings, into which it passes.

The alimentary bolus is directed towards the œsophagus, and carried into this canal by the peristaltic motion of the pharynx, which may be considered as the wide part of a funnel-like tube. Solid food passes behind the opening of the larynx, exactly covered by the epiglottis: liquids flow on the sides of this aperture in two depressions easily perceptible. The swallowing of fluids is more difficult than of solids; the particles of a fluid continually tend to spread; and, to prevent this separation, the organs are obliged to be more closely applied, and to compress the body to be swallowed with greater exactness. Thus it is constantly observed, in cases of impeded deglutition, from some organic defect in the parietes of the œsophagus, that patients, who are still able to take solids, have the greatest difficulty in swallowing a few drops of any liquid, and suffer extremely from thirst, at a time when they can satisfy their hunger.

Aliments descend in the œsophagus, propelled by the contractions of this musculo-membranous canal passing down on the spine, from the pharynx to the stomach: the mucus, copiously secreted by its internal membrane, envelops the food and facilitates its descent. The longitudinal *plicæ* or folds of the internal membrane assist the dilatation of this canal; yet when it is immoderately distended, severe pains arise, doubtless from a distention of the nervous plexuses of the eighth pair, which descend on the sides of the œsophagus, and are attached to it.

Digestion in the Stomach.

XIII. The aliments received into the stomach, there gradually accumulate, separating its parietes always contiguous when empty. In this mechanical distention of the stomach, it increases without reaction; yet it is not absolutely passive, its parietes give a kind of tonic motion to the matter contained by a general contraction, and it is to this action of the whole stomach that the ancients gave the name of *peristole.* In proportion as it dilates, its great curvature is pushed forwards, the foldings of the great epiploon separate, receive it in their vacuity, and apply themselves to the external part of the dilated stomach. The principal use of this duplicature of the peritoneum, in man, seems to be designed to facilitate the enlargement of the stomach, which distends chiefly at its anterior part; it likewise expands, though less apparently, on the side of the small curvature, and the two foldings of the gastro-hepatic epiploon separate like those of the great epiploon. Such is the utility of this duplicature of peritoneum, which may be considered as a necessary result, considering the manner in which this membrane is disposed, relative to the viscera of the abdomen. The peritoneum, going from the stomach to the liver to cover it, could not pass the interval that separates them without forming a kind of membranous bridge, supporting the vessels and nerves that pass towards the concave surface of the liver from the small curvature, or posterior part of the stomach. This gastro-hepatic epiploon, by the separation of the folds from which it is formed, can still assist the dilatation of the vena portæ, which is found with the assemblage of vessels, nerves, and excretory ducts of the liver, contained in the thickness of its right edge.

The great epiploon may be considered as a kind of *diverticulum* (this was the opinion of Professor Chaussier), towards which the blood is carried when the arteries of the stomach, contracted in the empty state of this viscus, cannot receive it. Does not the blood, flowing so slowly in these long small vessels, acquire an oleaginous nature, that renders it more proper to furnish the component parts of bile?

It is in the stomach that the mechanism of digestion is principally effected: it has always been considered the most important organ. The aliment received into its cavity becomes more fluid, undergoes a great alteration, and is converted into a soft homogeneous paste, known by the name of chyme. What are the means that induce this change? or, in other words, what is digestion in the stomach?

It would be useless to recapitulate the hypotheses successively formed to explain digestion; they may be reduced to *coction*, *fermentation*, *trituration*, *putrefaction*, and *maceration* of the food received into the cavity of the stomach. Physiologists are generally agreed at present, in considering digestion in the stomach as a solution of the aliment by the gastric juice. This liquid, copiously poured on the internal surface of the stomach when this viscus is irritated by the presence of food, is the production of arterial exhalation; it is neither acid nor alkali, and seems to be of a nature nearly analogous to saliva; the gastric juice, possessing great properties of solution, penetrates into the alimentary matter on all sides, separates and divides its particles, combines with it, changes its composition, and impresses qualities very different from those it possessed before this mixture. In fact, if a mouthful of wine or food be returned from the stomach some minutes after it has been received, the odour, taste, and all the qualities, both physical and chemical, of these substances, are so altered, that we can with difficulty distinguish them; and vinous liquors, more or less acid, are no longer susceptible of spirituous fermentation. The energy of the power of the gastric juice, perhaps exaggerated by some physiologists, is sufficient to reduce to a soft mass the hardest bones, on which certain animals subsist: it is very probable that its chemical composition is different and variable, and that it is acid, alkaline, or saponaceous, according to the nature of the aliment. Although gastric juice is the most powerful agent of digestion in the stomach, its dissolvent power has need of assistance from the action of several secondary causes, as heat, which seems to augment and concentrate itself in the epigastric region. So long as the exertion of the stomach continues, there is a sort of intestine fermentation, which should not be, in the full sense, compared to the motion by which fermentative and putrescent substances are decomposed; there is also a moderate and peristaltic motion of the muscular fibres of the stomach, which press the aliment on all sides, and perform a slight trituration, while the gastric moisture softens and macerates the food before it is dissolved; it may then be affirmed that the process of digestion is, at the same time, chemical, vital, and mechanical: the authors, therefore, of various theories to explain this function, have erred by attributing to one cause only, as heat, fermentation, putrefaction, trituration, maceration, and the gastric juice, that which is the aggregate result of all those causes united.

The aliment remains a greater or less time in the stomach, agreeably to the facility or difficulty of the necessary changes taking place. Gosse, of Geneva, has proved on himself, that the animal and vegetable fibre, the white of an egg boiled, white and tendinous parts, paste kneaded with butter, sebaceous substances, and those things which are not fermented or very little fermentative, make greater resistance to the gastric juice than the gelatinous parts of vegetables and animals, fermented bread, &c.; that the latter class of substances require only an hour for their complete dissolution, while the digestion of the former was not completed at the end of several hours.

During the time of digestion, both orifices of the stomach are closed; no gas, disengaged from the aliment, ascends through the œsophagus, unless in cases of bad digestion: slight chills are felt; the pulse becomes quicker and stronger, and the powers of life seem diminished in some organs, to be carried to the seat of the digestive process. The parietes of the stomach soon begin to act; their circular fibres contract in different parts of its extent: these peristaltic oscillations, at first vague and uncertain, become more regular, and are directed from above downwards, from left to right, that is, from the *cardia* towards the *pylorus;* its longitudinal fibres also contract, and thus approximate both terminations. In these different motions the stomach becomes parallel with the pylorus, and the angle formed by the duodenum is almost totally obliterated, which renders the passage of food easier. It has been remarked, that digestion proceeds better during sleep, when we lie on the right side than on the left, and this difference has been attributed to the compression made by the liver on the stomach. It should rather be considered, that, on the right side, the passage of food is accelerated by its own gravity: the situation of the stomach is naturally oblique, from left to right, and becomes more so in consequence of changes induced by the food.

The aperture at the pylorus is furnished with a muscular ring, covered by a duplicature of mucous membrane: this kind of sphincter keeps it closed during the time of digestion in the stomach, and does not give passage to the aliment until it has undergone a very material alteration. The pylorus, possessing a peculiar and extremely delicate sensibility, may be considered as a sort of vigilant sentinel, that prevents any thing from passing that has not suffered proper changes. Many authors quoted by *Haller* have been well aware that the food did not pass from the stomach successively in the same manner as it was received, but agreeably to its greater or less facility of digestion.

It would appear that there is a real selection of food in the stomach, for those aliments that admit of an easy digestion are directed towards the pylorus, which gives passage to them; while, on the contrary, such as are not sufficiently digested are not permitted to pass, but kept back in the stomach. This delicate feeling which we attribute to the pylorus; this exquisite sense, by which it exerts a kind of choice on the food that passes through, may be perhaps objected to; pieces of money, however, or other extraneous indigestible bodies, remain a longer or shorter time in the stomach before they go into the intestines, and present themselves several different times at the orifice of the pylorus, and do not get through till after it has been accustomed to their contact. It is the same with the gastric system as with a secreting gland; and in the same manner the commencement of excretory ducts, possessed of a sort of *elective* sensibility, do not receive the secreted liquor before it has undergone necessary preparations in the glandular parenchyma: so the pylorus, which may be considered the excretory duct of the stomach, does not admit the food, nor suffer it to pass into the intestines until it has been sufficiently elaborated by the action of this organ.

In proportion as the stomach becomes empty, the spasm of the skin ceases, a moderate heat succeeds the shiverings, the pulse becomes more evident and elevated, the quantity of insensible perspiration increases: digestion, then, produces a general motion, analogous to a feverish paroxysm; and this digestive fever, described also by the ancients, is most easy to be observed in women possessed of great sensibility. Nothing positive can be established on the duration of digestion in the stomach. The aliments go out of the stomach with more or less celerity, in proportion as they offer a greater or less resistance to those powers which serve to dissolve them, and agreeably to the energy and strength of the stomach, and activity of the gastric juice: five hours, however, may be considered the ordinary time of their presence. It is necessary to form an accurate idea how long digestion of the stomach requires to be accomplished, that it may not be disturbed by baths, bleedings, &c. which would remove towards other organs those powers, the concentration of which is necessary in the stomach for alimentary digestion.

The action of the parietes of the stomach ceases when this viscus is entirely liberated from the aliments that were in its cavity, but not before; the gastric juice, the secretion of which is not augmented by any stimulus, is no longer poured out by its arteries: and the parietes which come into contact with each other are only lubricated by the mucus copiously secreted by its internal coat.

Sometimes the action of the muscular fibres of the stomach is quite inverted; they contract from the pylorus towards the cardia; and this antiperistaltic motion, in which the contractions act with more force and rapidity, and in a manner decidedly convulsive, produces vomiting. The action of the abdominal muscles then connects itself with that of the stomach; the viscera are propelled upwards and backwards, by the contraction of the large muscles of the abdomen; the diaphragm ascends towards the chest: if it descended, in contracting, the œsophagus that passes between its two *crura* would be compressed, and the expulsion of food through the cardia could not be effected. It is also observed, that, during expiration only, any thing can pass from the stomach into the œsophagus: vomiting may depend on obstruction of the pylorus, on a too irritating impression of any substance on the parietes of the stomach; it may also arise from the effect of irritation of another organ with which the stomach sympathizes, &c.

Digestion in the Duodenum.

XIV. The aliments going out of the stomach pass into the duodenum, and there suffer new changes as essential as those they had undergone during digestion in the stomach.

The duodenum may be considered a second stomach, very distinct from the other small intestines, from its situation out of the peritoneum, its magnitude and distensibility, the size and fixidity of its curvatures, the great number of *valvulæ conniventes* with which its surface is lined, the immense quantity of lacteals that arise from it, but particularly on account of the bile and pancreatic juice being poured into it. If we pay attention to the disposition of the duodenum, to the peculiarities of structure, we see that every thing in this intestine must retard the passage of alimentary matter, and prolong its abode, that it may remain longer subject to the action of these fluids.

The duodenum, in fact, is almost entirely out of the peritoneum, which is a serous membrane, and, like all those which are expanded on the internal surface of large cavities, and reflected over the viscera contained in them, possesses very little power of extension, and does not seem to distend when these viscera dilate, except by the unfolding of its numerous duplicatures. The duodenum, attached by a loose cellular structure to the posterior part of the abdomen, can dilate so as to equal the stomach in magnitude, as we often see on opening subjects; the curvatures it makes are relative to the contiguous organs, and are almost invariably alike; finally, numberless valves, projecting from its internal membrane, increase friction, and at the same time giving a greater extent of surface, they permit a considerable number of lymphatic vessels to arise, which are destined to absorb the chyle, separated from the excrementitious part of our food in the duodenum, by the action of juices poured into it by the *ductus communis choledochus*, or junction of the excretory ducts of the liver and pancreas.

Concerning the Bile, and Organs that serve for its Secretion.

XV. The bile is a viscous liquid, bitter, of a yellowish colour, containing a great quantity of water, some albumen which is the cause of its viscidity, an oil, to which is joined the colouring, bitter principle, some soda, to which it owes its property of turning blue vegetable substances green, phosphates, carbonates, muriate of soda, phosphate of lime and ammoniac, and, according to some, oxyd of iron, and a kind of saccharine substance, analogous to sugar of milk. The biliary fluid, considered by the ancients as a kind of animal soap, useful to induce a more intimate union of alimentary matter, by combining its aqueous and oleaginous particles, is therefore very much compounded; it is aqueous, albuminous, oleaginous, alkaline, and saline. The liver, which secretes it, is a very large viscus, situated at the superior part of the abdomen, and chiefly fixed in the place it occupies by its adhesion to the diaphragm, and is affected by all its motions.

The hepatic artery, sent off to the liver from the cœliac, only supplies blood necessary for nutrition. The constituent principles of the liquor it secretes are contained in the blood of the vena portæ. This name is given to a peculiar venous system inclosed in the cavity of the abdomen, and formed in the following manner: the veins which carry back the blood from the spleen, pancreas, stomach, and intestinal canal, unite to form a large trunk that ascends towards the concave surface of the liver, and there divides into two branches; these are situated in a deep fissure in the substance of this viscus: they send off a prodigious number of branches into its substance, which divide like arteries, and have one termination by being continued into the *pori biliarii*, and another termination in the *venæ cavæ hepaticæ.* These last-mentioned veins, chiefly situated towards the convex or superior part of the liver, carry into the circulation of the blood that which has not been employed for the secretion of bile, and the nourishment to the liver; for they both equally arise from the vena portæ, and extreme ramifications of the hepatic artery.

The liver differs from all other secretory organs in not receiving its fluid for secretion from arteries: it seems that the bile, a fatty oleaginous liquid, in which hydrogen and carbon predominate, could only be extracted from venous blood, in which it is known that both these principles abound. The blood acquires venous qualities in proportion as it passes through the tortuous directions of the circulation; it becomes hydrogenated and carbonated better on account of the slowness of its motion. It is very obvious that every thing is naturally disposed to retard the circulation of hepatic blood, and afford it an extreme degree of all those properties which characterize venous blood; the arteries that furnish blood to organs, from which the vena portæ takes its origin, are either very much curved, as the *splenic*, or anastomose, frequently by arched branches, as the arteries of the intestinal canal, which present the greatest number of divisions into visible anastomoses of any arteries in the body. It will be seen in the chapter on the Circulation, how very proper this arrangement is to retard the passage of arterial blood. The blood, when arrived in the organs of digestion, remains there, either from the parietes of the viscera being hollow, pressed down, or contracted, or the peculiar structure of any of these organs that facilitates this stagnation.

The spleen seems to serve this purpose. This viscus, of a dark colour, and very little consistency, is situated in the left hypochondrium, and attached to the great cul-de-sac of the stomach. Whether does it receive the blood in the cells of its spongious parenchyma, or does it only pass slowly through the minute and winding ramifications of the splenetic vessels? No organ offers more varieties in number, size, form, colour, and consistence. Sometimes there are several spleens, at other times one, divided into several lobes by deep fissures: its size varies, not only in different persons, but in the same individual at different times of the day, according to the stomach, which, being full or empty, receiving or not receiving the arterial blood, compresses the spleen between its large extremity and the side, or exerts no compression over it.

The blood which fills the structure of the spleen, is blacker, more fluid, and abounding in oleaginous principles; and all these qualities, which induced the ancients to consider it a particular liquid that they called *atrabilis*, or black bile, arise from its long residence in the substance of this viscus. The branches which form the *vena portæ* by their union, have finer coats than other veins in the body; their internal surface is destitute of valves; they have much difficulty in distributing the blood contained in them: their action has so little energy, that it would not be sufficient for the propulsion of liquid, if the soft and alternate compression of the diaphragm and large abdominal muscles on the vicera did not assist its motion. When advanced to the liver, the circulation of the blood, completely venous, is still retarded by the increase of space containing it, as the aggregate diameter of the branches of the vena portæ hepaticæ is considerably more than that of the principal trunk. These vessels, enveloped in the parenchymatous structure of the liver, can only act feebly; it therefore passes slowly through its substance, and returns with difficulty into the circulation. The simple hepatic veins of any diameter are destitute of valves, and remain constantly open; their coats cannot approximate each other and contract upon the blood, which fills them by reason of their adherence to the structure of the liver: they open into the vena cava, very near the part of its termination in the right auricle. The reflux that venous blood undergoes during the contraction of this cavity of the heart, is perceived in these veins, and the blood repelled into the hepatic organ remains a longer time subject to its action.

The spleen, therefore, only performs preparatory functions, and may be considered auxiliary to the liver in the secretion of bile. It has been observed, that the quantity of this liquid increases after the extirpation of the spleen, and also that it is less yellow and bitter, and always imperfect. The epiploic blood is very analogous to that carried from the spleen; I would even affirm that it contains oleaginous particles, if the drops I have seen swimming did not come from the adipose structure of the omentum which suffers the liquid that fills its cells to flow, when a puncture is made to examine the blood contained in its veins.

The bile secreted in the substance of the liver (see the chapter on secretions) is absorbed by the biliary ducts, which, united, form the hepatic duct; this goes from the concave surface of the liver, and either carries the bile immediately into the duodenum, by means of the *ductus choledochus*, or into the gall-bladder. This small membranous sac, adhering to the inferior surface of the liver by cellular membrane, is entirely separated from that organ in several animals, and is only connected by the union of its excretory duct with the hepatic. Its internal coat, soft, spongy, folded, is always smeared with mucus, secreted by cryptæ-glands in its parietes: this mucus protects the surface of the gall-bladder from a too active impression of the bile that remains in it. The direction of the hepatic and cystic ducts being almost parallel, and the angle of their union so very acute, renders it very difficult to explain the passage of the bile into the gall-bladder. It seems that when the duodenum is empty, the bile from the hepatic duct, in part, regurgitates into the gall-bladder, there accumulates, becomes thicker, contracts a degree of bitterness which it did not before possess; the gall-bladder, therefore, is employed as a reservoir for a portion of the bile, which, in remaining there, is perfected, becomes thicker by the absorption of its aqueous parts, of a darker colour, and more bitter.

When the duodenum is filled with chyle, the irritation it produces on the parietes of this intestine is transmitted to the gall-bladder by the *ductus cysticus* and *ductus choledochus:* the pressure of the distended intestine on the gall-bladder assists this excretion. The hepatic bile is also more copiously poured into the duodenum during digestion by the liver, which participates in the irritation of the gastric organs in carrying on a more active secretion. The cystic and hepatic bile, mixed in the ductus choledochus before they are poured on the alimentary matter, are changed by the pancreatic juice. The excretory duct of the pancreas, a glandular organ, the structure of which has so great an analogy to the parotid glands, that some physiologists, presuming on the identity of their functions, have called it the salivary gland of the abdomen, unites itself to the bile duct before this opens on the internal surface of the duodenum, after having obliquely passed between the coats of this intestine. It arises from the internal structure of the pancreas, by a great number of small vessels that run from its sides like the feathers of a pen into one common trunk; its diameter increases in proportion as it approaches the head or large extremity of the pancreas, situated on the right side in the second curvature of the duodenum. Nothing particular is known of the pancreatic juice; the striking resemblance of the pancreas to the salivary glands induces a presumption that it is very analogous to saliva; we are also ignorant of its quantity, which ought to be considerable in proportion to the great number of nerves and vessels distributed in its glandular structure, and should be increased by the irritation produced by aliments in the duodenum.

This mixed pancreatic-biliary fluid poured on the mass of chyme, penetrates, liquefies, and animalizes it, separates the chyle from the excrementitious part, and suffers every thing to pass down which is not nutritious. In effecting this, the bile seems to divide itself into two parts; its oleaginous colouring and bitter portion goes with the excrements, envelops and invests them with stimulant qualities, necessary to excite the action of the intestinal canal; its albuminous and saline portion mixes with the chyle, forms one of its constituent parts, and, being absorbed with it, is carried into the circulation. In fact, we perceive two very distinct parts in the mass of aliment after it has suffered this mixture: one is of a whitish matter, like milk, which is on the surface, and only forms a very small portion of the whole; the other is a kind of yellowish mass, in which it is difficult, when digestion is perfect, to distinguish the various aliments. When the liver is obstructed, and the bile does not flow in sufficient quantity, the fæces are dry and discoloured; patients labour under obstinate costiveness; the excrement, deprived of the colouring bitter part of the biliary fluid, does not sufficiently irritate the intestinal canal.

Action of the small Intestines.

XVI. The alimentary mass decomposed by the bile, or rather by the pancreatic-biliary fluid, divided into two portions, one chylous, the other excrementitious, after remaining a longer or shorter time in the cavity of the duodenum, passes into the jejunum and ileum, small intestines which are with difficulty distinguished from each other, since their relative extent is variable, and dependent on the arbitrary distinctions of anatomists.

The redness of the parietes of the jejunum, the state of vacuity of this intestine, its position in the umbilical region, the great number of *valvulæ conniventes*, cannot serve to distinguish it from the ileum, since the colour of the intestinal canal is very variable in different points of its extent; matters distending it occupy various portions of this canal, when digestion is more or less advanced at the time of examination; the circumvolutions descend into the cavity of the pelvis, or ascend towards the epigastrium, according to the state of plenitude or vacuity of the bladder and stomach; and finally, the number of circular foldings called *valvulæ conniventes*, gradually decreases as we pass towards the ileum. Winslow settled this difficulty by taking two fifths of the superior part of this intestine for the jejunum, and the remaining three fifths for the ileum. This division is entirely arbitrary, and also useless; for there is, perhaps, only one occasion in which it would be necessary to distinguish the jejunum from the ileum. When we operate for an hernia with gangrene, the establishment of an artificial anus would be more easily settled if we could be certain that the sphacelated part belonged to the latter of these intestines: but it is absolutely impossible to become certain of it.

The jejunum and ileum alone form almost three fourths of the whole length of the intestinal canal; they are narrower than the duodenum, and not so extensible, because the peritoneum, which forms their external coat, is reflected over all its surface, except the posterior part, by which vessels and nerves enter. It is by this edge that they are attached to the mesentery, a membranous substance formed by a duplicature of peritoneum, that protects the vessels and nerves going to the jejunum and ileum, prevents their being entangled, and obviates intussusception; yet it has been found in some extraordinary cases that this latter event has taken place, not without very imminent danger, and patients generally die afflicted with the most excruciating colics that nothing can alleviate. The progress of alimentary matter in its passage through the small intestines is retarded by their numerous curvatures, justly compared by some physiologists to the directions of a brook that winds through and fertilizes the earth it supplies with moisture. These frequent windings of the intestinal canal occasion the presence of aliment to be sufficiently prolonged for the chyle, pressed from its excrementitious parts by the peristaltic motion of the intestine, to present itself to the inhalant mouths of the lymphatics which absorb it. These chylous absorbents are more particularly numerous on the surface of the valvulæ conniventes, circular foldings of the internal membrane that are more distant from each other the more we advance towards the ileum. The course of aliment is not only retarded by these valves; but from the projections formed by them plunging into the mass, when the intestine contracts, the lymphatics arising from their surface seem to endeavour to seek the chyle they are destined to absorb.

The number of valvulæ conniventes diminishes with the lymphatics, and the passage of alimentary matter is gradually accelerated in proportion as it parts with its nutriment. The mucus, copiously secreted by the internal membrane of the small intestines, envelops the mass of chyme, and facilitates its progress by rendering it more lubricating; the intestinal juice produced by arterial exhalation, penetrates, liquefies it, and augments its quantity. This fluid, which seems to be of a gelatino-albuminous nature, containing different salts in solution, is, in a great measure, excrementitious; its quantity, estimated by the diameter of mesenteric arteries, and the extent of intestinal surface, should be very considerable; yet it is hardly possible for it to be so much as eight pounds in twenty-four hours, as Haller asserts, who has generally exaggerated the product, as will be mentioned in the article of Secretions.

Digestion in the large Intestines.

XVII. The alimentary matter, almost entirely deprived of the nutriment it contained, passes from the ileum into the cœcum; it then enters the large intestines, which are more capacious, but not so long as the smaller, since they only constitute one fifth of the whole length of the intestinal canal. A valvular ring, of muscular-membranous structure, is found at the oblique insertion of the ileum into the first of the large intestines. This ring, named after Eustachius or Bauhine, who have been considered the first discoverers of it, although that honour should be given to Fallopius, is formed of two semicircular segments, the right side of which is unconnected, and situated on the side of the cavity of the cœcum. The more the parietes of this intestine is distended, the less easy becomes a retrograde motion of the mass contained; both extremities of the valve are spread, and their edges approximating and touching each other, like the sides of a button-hole when its ends are pulled in a contrary direction: the muscular fibres which enter into its composition render it also capable of contraction. It can permit an easy passage of substances from the ileum into the cœcum, and make a powerful resistance to their return into the small intestines. Some facts induce us to believe that its resistance is sometimes overcome, and that a clyster pushed with great force would pass beyond it, and be returned by vomiting. The large intestines may be considered as a kind reservoir, destined to contain, for a certain time, the excrementitious parts of our solid food, and to obviate the extreme inconvenience of continually evacuating them.

As the peritoneum does not entirely surround them, a considerable dilatation may take place towards the cellular structure that connects them to the parietes of the abdomen; the muscular coat which, in some measure, is the principal part of the intestinal canal, is not every where composed of circular and longitudinal fibres: the latter, collected into fasciculi, form three bands, not very broad, in the intervals of which the coats of the intestine, being relatively weaker, must possess greater power of extension. These longitudinal fibres, being also shorter than the intestine itself, bend it laterally, and give rise to a number of cavities, and internal cells, externally marked by projections separated by alternate contractions. If we add to these peculiarities of structure, that the contents are obliged to ascend contrary to their own gravity in the cœcum and part of the colon; that the curvatures which form the S (the sigmoid flexure) of the latter, are very evident; and lastly, that the rectum, before it terminates externally by a narrow aperture, suffers a marked dilatation: we shall find that every thing in the large intestines serves to protract the presence of the excrements.

The vermiform appendix of the cœcum is too narrow, in man, to be used for this purpose; in herbivorous quadrupeds it is larger, and sometimes several exist, which may serve as a reservoir for the fæces. Its existence in man only indicates a point of analogy with animals, to which it is really useful, and concurs to establish the proof, that nature is content to sketch out certain organs in some species that are carried to perfection in others, as if she designed to mark the existence of a connexion between all the beings to which she has distributed motion and life.

The aliment, during its residence in the large intestines, becomes entirely fæcal by parting with the small quantity of chyle it contained. The number of absorbent vessels progressively diminishes from the cœcum to the rectum; their paucity explains how difficult it is to nourish the body by means of clysters when deglutition is impeded: the excrement becomes thicker, hardens, and forms itself in the cells of the colon; afterwards they are propelled by a peristaltic motion towards the rectum, in the cavity of which they accumulate until they produce a sufficient impression on its parietes to induce expulsion.

Excretion of the Fæces.

XVIII. When the necessity of evacuating the fæces is perceived, the rectum contracts, while the diaphragm descending, and the large muscles of the abdomen going backwards, push the abdominal viscera towards the cavity of the pelvis, and compress the intestines filled with fæcal matter: the perineum sensibly descends during these efforts, and the fibres of the levatores ani seem to suffer a slight elongation. The united action of the rectum and abdominal muscles overcomes the resistance of the sphincters; a dejection of fæces is the consequence; it is facilitated by the humour from the mucous lacunæ of the rectum, which, pressed by its contents, empty themselves, and lubricate the verge of its inferior aperture. When this is over, the diaphragm is raised, the large muscles of the abdomen cease to push the contents of the cavity downwards and backwards; the perineum reascends, and the sphincters close until a new occasion excites an exercise of the same action.

The necessity of evacuating the fæces is more frequent in children than in adults; because, in the early age of life, the sensibility of the intestinal canal is greater, the fæces more liquid, and digestion more active. As we advance in age, the sensibility diminishing, contractility experiencing a proportionable diminution, and the secretions becoming also less abundant, the bowels are indolent, the stools less frequent, and not liquid: they are also not so numerous nor copious in women as in men, either because the digestive powers extract a greater proportion of nutritive matter, or that their intestinal secretions, compensated by the menstrual periods, add less to the mass of excrement. The excretion of fæces is induced by injecting liquids into the rectum, which dilute and detach them from the parietes of the intestines, and by exerting a peculiar irritation on these parietes or coats, to which they have not been accustomed, excite their contraction.

The fetid smell of the fæces depends on the commencement of putrefaction that they undergo in the large intestines. This alteration is mostly accompanied with a disengagement of gas, in which sulphurated hydrogen is predominant: it is from the presence of this gas, which sometimes escapes, at other times impregnates the excrements, that they have a property of blackening silver. In the excrements may be discovered the colouring part of vegetables, such as green in spinage, red in beet-root; fibrous parts are found both vegetable and animal, and hard skins and seed covered with their epidermis. The digestive juices have so little effect on this covering, that seeds which have not been broken by the organs of mastication, very often preserve the property of vegetation.

Secretion and Excretion of Urine.

XIX. The liquid absorbed with the chyle by the lymphatics of the intestinal canal, dilutes the nutriment extracted from solids, and serves as a vehicle for it; when carried into the mass of blood it augments its quantity, diminishes its tenacity, and renders it more fluid: in passing through the long passage of the circulatory system it moistens every part, becomes loaded with particles detached by the motion of life; then being carried to the urinary organs, it is separated from the mass of humours, carrying off a great number of those principles, the retention of which, in the animal economy, would not fail to produce an evident derangement in the exercise of the functions.

XX. The celerity with which we pass certain diuretic drinks, by urine, has induced many to believe that there existed an immediate communication between the stomach and urinary bladder; but, besides that no person has ever demonstrated these particular ducts carrying the urine from the gastric cavities to the bladder, without passing through the long process of absorption and circulation; the learned Haller has decided, on the most exact calculations, that the size of the renal arteries, the diameter of which is one eighth of the aorta, and the velocity with which the blood circulates, are sufficient to explain the promptitude of the passage of certain liquids into the urinary system.

A thousand ounces of blood pass through the renal structure in the space of an hour: admitting that this fluid contains only a tenth part of materials necessary to form urine, an hundred ounces, or twelve pints and a half, could be separated from it in this short interval; and a larger quantity of this liquid is never secreted in an hour, however copious and diuretic the drink may be. Yet we shall see, in treating of absorption, that it is not absolutely impossible, from the numerous anastomoses of lymphatics, that this order of vessels should carry, in direct motion, a liquid from the stomach to the bladder. It would be superfluous here to point out the varieties seen in the kidneys, in number, size, and situation. These two bean-like viscera, formed by the union of twelve or fifteen glandular masses, separated in the fœtus and some quadrupeds, are attached to the posterior part of the abdomen behind the peritoneum, and are there enveloped by a cellular structure of different degrees of thickness, but particularly remarkable by the suet-like consistence of the fat contained in its cells.

If ever human industry should be able to reveal the secret of the intimate structure of our organs, it seems probable that the kidneys would give the first solution of this problem. The coarsest injections pass through the renal arteries with facility into the ureters, or excretory ducts of the kidneys; a convincing proof of an immediate connexion between the small arteries, which are disposed of in a peculiar manner, and which, with the minute veins, form the external or cortical substance of the kidneys, and the rectilinear ducts, or *tubuli uriniferi*, which, placed in conical fasciculi in the internal part of these organs, constitute what has been called the tubulous and mammary substance of the kidney. The passage of injections from the arteries into the renal veins is equally prompt; and I have often seen the thickest liquids pass, at the same time, from the ureters and emulgent veins. This free communication between the arteries, veins, and excretory duct of the kidneys, shows the rapidity of the passage of the blood through these organs, the compact texture of which only admits of moderate dilatation; and the possibility of a sort of filtration of the urinary liquid, the secretion of which would only be a series of chemical or mechanical alterations the blood undergoes in passing through small vessels, the diameter of which suffers a progressive decrease. This was, at least, the opinion of Ruysch, whose system on the exact structure of our organs, and the immediate communication of blood-vessels with the excretory ducts, was chiefly established on demonstration from his fine injections thrown into the renal arteries.

The kidneys have a more obtuse sensibility, and not such energetic activity as other glands possess; vital action is less concerned in the secretion they carry on, and their functions more easily fall under chemical and hydraulic explanations.

XXI. If, in fact, we wished to apply the fundamental laws on the mechanism of secretions to the urinary organs (see the chapter on Secretions), we should soon discover that these organs are not rigorously under their influence. Of all animal fluids, the urine is that which presents the most numerous and most variable qualities; not only do extraneous substances manifest themselves, affect an alteration, and even a change in its composition; other liquids can be mixed, and render it difficult to be distinguished. Thus, investigators, worthy of our confidence, have discovered in the urine, bile, fat, milk, blood, pus, as may be easily seen in reading the great Physiology of Haller, where these facts are collected together. The kidneys, therefore, have a less active degree of sensibility than other secretory glands; they feel less, if I may be permitted to use the expression, the sensation produced by different substances of which the blood is the vehicle. Their action likewise has less energy; it does not so completely alter the liquid exposed to its influence; it does not change the heterogeneous qualities of those things which are found united, and suffer them to pass in all their purity.

This assemblage of elements which enters into the composition of the urine, was doubtless known to the ancients before it was demonstrated by modern chemists; when they considered it as a kind of extract of animal substance, a true lixivium, by which every thing impure in the animal economy was washed away: they gave it the name of *lotium*, which signifies such a quality.

Finally, the secretion of urine is effected in a uniform manner; it is continual, or at least does not present us so distinctly the alternate states of action and rest so easily distinguishable in other secretory organs. When a catheter is introduced into the urinary bladder for retention of urine, and suffered to remain, the urine is continually evacuated *guttatim*, and would inundate the patient's bed if a cork were not put into the aperture of the instrument. We see in the *Mémoires de l'Académie des Sciences, pour l'Année* 1761, the history of a singular conformation of the bladder. This musculo-membranous sac came out externally through an opening in the inferior part of the linea alba; it was turned inside out, so that its mucous surface was outwards, and it was easy to distinguish the continual dribbling of the urine by the orifice of the ureters; and to study the varieties that this discharge offered, either with regard to the quality of the fluid, or the quantity which flowed in any determinate time, which were different, according to the state of sleep or watching, the quantity of drinks, and their quality being more or less diuretic.

The liquor contained in the urinary ducts is crude and imperfect; its principles are ill combined, as may be easily seen by compressing the tubular structure of the kidneys in a dead subject. It is perfected in passing through these ducts, acquires all the qualities which constitute urine, drains to the surface of the mamillary processes, and flows into the membranous *calices* by which the obtuse terminations of these conical tubes are surrounded. These united *calices* form the pelvis or expanded part of the ureters, which are membranous canals through which the urine continually descends into the bladder; it passes down by its own gravity, and particularly by the action of the parietes of the ureters, which only possess a certain degree of contractibility. To these essential causes, we may add the continual pulsation of the renal arteries, behind which the pelvis of the kidney is situated; also the action of the iliac arteries before which pass the ureters just before they enter the cavity of the pelvis; the alternate pressure of the viscera of the abdomen, in the motions of respiration; the shaking that arises from bodily exercises, as riding, walking, running, &c. &c.; the pressure of columns of fluid near the kidneys; and the want of resistance on the side of the bladder.

XXII. The urine continually enters, drop by drop, into the bladder, separates its parietes, without producing any perceptible impression, as they are accustomed to its presence. In order for the urine to accumulate in this muscular membranous sac, situated out of the peritoneum in the cavity of the pelvis, behind the ossa pubis, above which it is not raised in adults, except in cases of very great repletion, it should neither flow out through the urethra, nor back into the kidneys by the ureters. This retrocession is obviated by the oblique insertion of these canals, which pass some distance between the muscular and mucous coat of the bladder, before they open on its interior surface towards the posterior part of the bladder, by orifices narrower than their cavity. The internal membrane of the bladder elevated at these apertures, makes them appear as if furnished with a kind of valve, which applies itself more accurately to the orifices when the urine contained in the bladder, separating its parietes, presses together the coats of which it is formed, and between which the ureters penetrate for the space of seven or eight lines.

The urine flowing into the bladder is obliged to exert a certain force to separate its parietes, on which the intestinal viscera press. This force is only that which causes the liquid to flow in the ureters, and although not considerable, it will appear quite sufficient if we pay attention to this fact, that fluids which pass from a narrow canal into a more extensive cavity, act on all the points of the parietes of this cavity, equal in surface to the diameter of the canal, with a force equal to that which causes them to flow into the latter; so that if the urine descends through the ureter with one degree of force, and the internal surface of the bladder has a diameter a thousand times larger than the ureters, the force will be a thousand times multiplied.

The pressure of the urine accumulated in the bladder on the inferior parts of the ureters, does not diminish the force that causes them to flow into these canals, and propels them into the bladder; for the column of liquid descending through the ureters being higher than that contained in the bladder, these two organs represent a reversed syphon, the long branch of which is formed by the ureter.

The causes that retain the urine in the bladder are, the contraction of its sphincter, a muscular ring with which the orifice of the urethra in the bladder is surrounded; the angle formed by this canal after leaving the bladder; and, lastly, the anterior fibres of the levatores ani that are attached to the neck of this organ, also surrounded and supported by the prostate gland. These fibres, which can compress the prostate on the neck of the bladder, and elevate the latter against the symphysis pubis, have been called by Morgagni false sphincters of the bladder (*pseudo-sphincteres vesicæ*).

The urine deposited *guttatim* in the bladder gradually separates its parietes, the musculo-membranous sac becomes elevated, raising up the circumvolutions of the ileum and the peritoneum, before which it is situated, but behind the recti muscles of the abdomen, with which it is in immediate contact. These connexions of the dilated bladder with the peritoneum, detached from the anterior parietes of the abdomen to give place to the dilated bladder, then situated between it and the muscles forming the parietes, explains the possibility of perforating above the pubis to relieve retention of urine, without touching the peritoneum by this puncture. The urine remains a longer or shorter time in the bladder in proportion as it is more or less capacious, its parietes more or less extensible and irritable; regulated also by the variable, acrid, or stimulant nature of the urine. Thus old men, whose bladder only possesses an obtuse sensibility and moderate contractility, void their urine less frequently; it accumulates in greater quantity, and the bladder often evacuates it with difficulty. The use of diuretic drinks, particularly cantharides, renders the urine more stimulant; it irritates the coats of the bladder, and excites it every moment to contraction. Every cause of irritation existing in the bladder itself, or its vicinity, causes a more frequent desire to pass the urine; this is observed in calculous affections, the piles, gonorrhœa, &c. During its abode in the bladder, the urine becomes thicker from the absorption of its more fluid parts, its elements are more intimately combined, sometimes it even seems to suffer a commencement of decomposition.

XXIII. When we experience a sense of weight in the pelvis, joined to a kind of *tenesmus* extending along the urethra, informing us of the necessity of voiding the urine, either from its action on the muscular fibres of the bladder, or by the irritation it occasions on the nerves distributed on the structure of its internal coat; then we contract the bladder; assisting its action with that of the abdominal muscles and diaphragm, we liberate ourselves from the urine by a mechanism very analogous to that of the excretion of the fæces (XVIII.) We should observe, that in a natural state the assistance of auxiliary powers only destroys the equilibrium that exists between the contractions of the bladder, and the resistance opposed by the retentive causes to the flowing out of the urine. We cease to make efforts after having once contracted the diaphragm and abdominal muscles, to press the intestines on the bladder and procure the evacuation of the first jet of urine; and the bladder only, which is always assisted by the weight of the viscera, completes the excretion. We do not repeat this first effort, except in cases in which we wish to accelerate the expulsion of urine; in the excretion of the fæces, on the contrary, the muscular coat of the rectum has always occasion to be assisted by the powers of expiration, as they are of a more solid texture, and expelled with greater difficulty than the urine.

The urine is projected with a greater force through the canal of the urethra in proportion as it passes from a large cavity into a narrow tube. The greater or less energy of the muscular coat of the bladder varies the distance of propulsion in the urine: we know that, in old men, it is so much weakened that the urine can scarcely be propelled some inches beyond the orifice of the urethra, which should not be considered as an inert tube in the performance of this office; it contracts upon the urine, accelerates its discharge, and is assisted in this action by the bulbo-cavernous muscles, which some anatomists have named after their use, acceleratores urinæ.

It is by the action of these muscles that the last drops of urine are expelled, which remain in the canal when the bladder is completely emptied. The tonic and contractile action of the urethra is so marked, that we should enumerate its spasmodic affection among the number of causes that sometimes render it difficult to pass a catheter. If an injection be thrown into it, the moment that the pipe of the syringe is withdrawn, which should have entirely closed the external orifice, the distended parietes react forcibly on the liquid injected, and expel it by a sudden jet.

The internal surface of the bladder and urethra is covered by a membrane, the glandular cryptæ of which secrete a viscous humour, proper to defend the parietes of these organs from a too active impression of the urine, and to facilitate its discharge. This membrane, more extensive than the cavity it covers, forms a number of folds that are obliterated when dilated by the presence of the urine: the mucous humour, copiously secreted in catarrhal affections of the bladder, likewise becomes more viscid and albuminous. That which the urethral glands secrete, changes its qualities, augments in quantity by the stimulus of venereal virus, and forms the matter of discharge in gonorrhœa. The orifices of these glandular cryptæ, directed forwards, may stop the point of the catheter or bougie, and become another obstacle to the passage of those instruments.

When this operation is performed for simple paralysis of the bladder, it is better to use a very large catheter, on which the coats of the urethra may distend without forming *plicæ*, the round extremity of which cannot be enveloped in the mucal lacunæ of this canal.

In cases of retention of urine, when the bladder raises itself above the pubis, its fundus ascends, and at the instant of extreme repletion, like the uterus in an advanced state of pregnancy, it seems to make an effort to emerge from the pelvis into the cavity of the abdomen. Women cannot be relieved, under these circumstances, without making a large curve in the female catheter.

The excretion of the urine cannot take place at the same time as the passage of the fæces when indurated, for they compress the prostatic and membranous part of the urethra, situated anterior to the inferior extremity of the rectum. It is also difficult, and often impracticable in a powerful erection, since the parietes of the canal are closely applied to each other by the distention of the corpora cavernosa and corpus spongiosum of the urethra; besides, the sensibility of the urethra is changed, and it becomes only fitted to the ejection of the semen.

When the bladder is completely emptied, it contracts itself behind the ossa pubis; the tumour formed above this part, when distended, subsides; the abdomen is less projecting, the respiration easier, and the body feels lighter. The bladder cannot be completely emptied unless the pelvis be moderately inclined forwards; for otherwise the fundus would be lower than its cervix, and retain a small quantity of urine.

Physical Properties of the Urine.

XXIV. It is extremely difficult to determine the exact quantity of this fluid, which is variable in an healthy person, according to the quantity of drink, its degree of diuretic quality, the state of sleep or watchfulness, the abundance of other secretions, and particularly perspiration. No secretion is more varied in quantity, as may be seen in the calculations made on this head by a great number of physiologists. Sometimes we pass less water than the quantity of fluid drunk, at other times it exceeds the liquid food; yet we may assert, that the quantity of urine in twenty-four hours is equal to that of insensible perspiration in the same time; and that it may be thus estimated at about three or four pounds in an healthy adult. Its colour varies from yellow, with a light tinge of orange, to a deep orange, approaching to red: its odour and taste are so characteristic, that it cannot be mistaken for any other animal liquid. Its colour is generally deeper, its smell and taste more pungent in proportion to the smallness of its quantity, the power and energy of the circulatory system, and the abundance of animal food. We know how fetid and small the quantity of urine is of carnivorous animals; what a disgusting odour exhales from that of a cat! It is always heavier than distilled water, and more or less so in proportion to the salts and other substances it keeps in a state of solution; it is slightly viscous, but not ropy, like the serum of the blood, bile, saliva, and other albuminous fluids.

The chemical Nature of the Urine.

XXV. Its properties are always more marked in the male and vigorous adult, than in children, women, and debilitated habits. The chemical analysis of this fluid demonstrates eleven substances dissolved in a great quantity of water: these are, the *urea*, a gelatinous animal liquor; muriates and phosphates of soda and ammoniac, separate, or united in a triple salt; phosphate of lime, phosphate of magnesia, phosphoric, uric, and benzoic acids. Besides these, which constantly exist in the human urine, this liquid can contain a great number of other substances;

and if it be true that the urinary system may be considered the emunctory of the whole economy, it must be evident that every component principle discovered in the analysis of our solids and fluids, must be present in a greater or less degree under different circumstances of life. From thence, doubtless, arise the numerous varieties observed in the urine by different chemists, who have studied the nature of this liquid, by leaving it to a spontaneous decomposition, or proceeding to various experiments.

As the urine is, of all our liquors, the most easily putrescent, it should be examined soon after its evacuation from the bladder: it is then evidently acid, but its principles soon suffer a change, particularly if the heat of the atmosphere be such as to accelerate this effect; it becomes turbid, its constituent parts are decomposed, and form several precipitates. The urine and gluten, which are the only fermentative and changeable principles, furnish acetous acid, ammoniac, carbonic acid; and from the action of these newly formed substances and primary elements, arise a multitude of other compounds, the distinction of which belongs to chemists.

Of all the constituent parts of urine, there is none more essential than a sirup-like, crystallizable, and deliquescent matter, to which the celebrated Fourcroy has given the particular name of urea. This principle, to which the urinary liquid owes its characteristic qualities, its particular colour, odour, taste, distinguished by several chemists, who have traced some outlines of its history in expressing it by different names, agreeably to the ideas they had of its nature, has only been thoroughly understood since the recent labours of that great Professor (see his work called Systeme des Connoissances Chymiques, &c. 10 vols. 8vo. p. 155 and seq.) It is a compound in which azot predominates, as proved by the very great quantity of ammoniacal carbonat it yields in distillation; it may be considered as a product animalized to the highest degree possible, having so great a tendency to putrid fermentation, that, retained in the animal economy, it could undergo that change and even overcome the antiseptic influence of the vital powers, if nature were not to exonerate herself from it by the urine.

A sufficient attention has not hitherto been given to the symptoms of a urinous fever, or affection occasioned by a too long retention of this liquid in the cavity of the bladder. I have frequently had occasion to observe, that no disease gave better marked signs of what physicians call putridity. The urinous and ammoniacal odour exhaled from the whole body in sickness, the yellow, greasy moisture covering the skin, the great thirst, the dryness and redness of the tongue and throat, the frequency and irritation of the pulse, joined to the softness and flaccidity of the cellular membrane; all indicate that the animal substance is menaced with speedy and prompt decomposition. The urea, combined with a certain quantity of oxygen, seems to form the particular acid of urine, which alone constitutes the greatest number of *calculi* in the bladder: it resembles urea, because its crystals, when acted on by fire, exhale a great quantity of carbonat of ammoniac, but differs essentially from it by its easy concrescibility. In fact, it crystallizes as often as the urine cools, and forms the greater part of the sediment. This acid is so weak, that some have considered it as a simple oxyd, and it has been called by Fourcroy and Vauquelin uric acid.

Besides these substances possessing so great a degree of animalization, it is necessary to observe, that phosphorus, which is very considerably animalized, enters the human urine in great abundance. Independent of the phosphoric salts it contains, there is always found a certain quantity of disengaged phosphoric acid, which holds in solution the phosphate of lime, and gives the urine its manifest acidity when examined directly after its expulsion from the bladder. Thus it was from urine that phosphorus was first extracted by those who discovered it, and long used for the purposes of the arts or manufactures; but it has been seldom employed since the discovery of the phosphoric acid in the terrene salt of bones, which has rendered the preparation of phosphorus less expensive and difficult.

Certain substances give the urine a particular odour. We know that remaining a few minutes in a room lately painted with the oil of turpentine, is sufficient to afford a violet smell to the urine evacuated soon afterwards: asparagus also occasions a very remarkable fœtor in the urine.

XXVI. Besides these accidental varieties presented by the urine, varieties which are undeterminable, since this liquid has not at all times identically the same composition, does not contain the same principles in the same subject at different times of the day, but is dependent on the nature and quantity of food and drink taken, the exercise, affections of the mind, &c.; it offers constant differences relative to the length of time after meals, the age of individuals, and the complaints with which they may be afflicted.

Physiologists have long distinguished two, and even three species of urine, according to the time of its being evacuated, and called them *urine of the drink*, *urine of the chyle*, *urine of the blood.* The first is an aqueous liquid almost void of colour, which often retains, in a remarkable manner, the qualities of the drink, is evacuated soon after taking it, and has hardly any of the characters of true urine: the urine of the chyle or digestion, evacuated two or three hours after meals, is better elaborated, but not yet complete in all the constituent principles of this fluid.

Finally, the urine of the blood, which is passed seven or eight hours after meals, or in the morning after the repose of the night, has all the properties of urine in an eminent degree; this is the kind, therefore, which chemists take for their analysis. The imperfect state of the two first species of urine serves to prove, more decidedly than the rapidity of their secretion, the existence of particular passages which carry it directly from the stomach and intestines into the bladder.

The urine of infants and nurses contains very little phosphate of lime and phosphoric acid; it is not until after ossification is finished that these elements are found in abundance in the urinary fluid. That of old men, on the contrary, contains a great quantity of them; the bony system, already overcharged with phosphate of lime, refuses to admit more of it. This saline substance would ossify every part as it does sometimes in the arteries, ligaments, cartilages, and membranes, if the urine were not to remove the greater part of this superabundant portion.

In *rachitis* it is by the urine that the phosphate of lime passes off, the absence of which causes the softness of bones. On the approach of an attack of the gout, the phosphoric principle of the urine diminishes, and seems to be determined towards the joints, to induce arthritic concretions in their vicinity.

The great quantity of saline and crystallizable elements that enters the composition of human urine, accounts for the frequency of concretions formed in this liquid. Urinary calculi have long been considered as formed of one substance only, which the ancients believed analogous to the earth of bones, and which Scheele thought was the acid. The late experiments of Fourcroy and Vauquelin have proved that the constituent principles of urine are too numerous and compound to furnish constantly calculations of the same nature; that the urinary concretions are mostly formed by the uric acid, contain urate of ammoniac, phosphate of lime, ammoniaco-magnesian phosphate, oxalate of lime, of silex; and that these substances singly, doubly, or combined in a triple proportion, would form a basis for near six hundred calculations which they have analyzed. How extensive soever these researches have been, there is reason to believe, that, if continued by the same chemists, they would still offer more variable results; for, as there is no entire particle of the body that cannot be evacuated by the urine, and manifest itself in that liquid, so it must be conceived, that, under different circumstances, which it is impossible to determine or foresee, every thing in the body possessing a power of concretion may become a subject of calculation in the urine discharged.

This diversity of elements that enter the composition of urine; the deficiency of properties by which we can recognise their nature; the sensibility of the coats of the bladder, which *reactives*, by means of which we might dissolve concretions so often formed in its cavity, dangerously irritate, should convince us how extremely difficult, if not impossible, it is to discover a lithontriptic, that would obviate the necessity of a surgical operation, the danger and difficulty of which have, perhaps, hitherto been too much exaggerated.

The activity of the urinary system in the inhabitants of temperate climates is the cause to which the frequency of calculous affections in Holland, England, and France, should be attributed; while they are not so frequent in more southern regions, where the urinary secretion seems much superseded by insensible perspiration, the quantity of which is always in an inverse proportion to that of the urine. *Diabetes*, or immoderate flowing of urine, a disease that appears to be produced by an excessive relaxation of the renal structure, has only been observed to exist in many instances in cold moist countries, as Holland, England, and Scotland: it is more rare in France and Germany, and perfectly unknown in hot climates. This relaxation in the structure of the kidneys depends on the fatigue of the urinary organs too much exerted, as proved by the success of tonics and astringents in the treatment of this disease.

Affections of the cutaneous organs, on the contrary, seem peculiar to the inhabitants of southern countries. The leprosy, which originated in Judea; the red disease of Cayenne; the pian of Java; the yaws, the elephantiasis, dartous and scabious eruptions, are more common to people inhabiting the torrid than the temperate zones. In the climates near the equator, the surface of the body, habitually in contact with a scorching atmosphere, is affected with a violent excitement; the skin, from increased irritation, secretes more freely; perspiration is so copious, that it quickly debilitates those who, coming from a distant country, are not yet accustomed to it. The cutaneous system is in a state of predominant activity with relation to the urinary system, the action of which proportionally decreases. These varieties in the energy of both systems easily explain the diversity of their diseases; for, by a general law, the more an organ, or system of organs, exerts itself, the more it is exposed to diseases, which are only derangements of its action.

XXVII. We shall finish this article of digestion by pointing out some of the principal differences that the digestive organs present in animals of red and warm blood. The insertion of the œsophagus into the stomach is nearer the left extremity of the stomach, and the great cul-de-sac of this viscus has less extent in proportion as animals exist more exclusively on flesh, which easily passes through its necessary alterations, and has no occasion to remain long in the stomach to be completely digested. In quadrupeds that do not ruminate, the cul-de-sac forms the greater part of the stomach, as the œsophagus enters nearer to the pylorus; in some, as the hog, the stomach is even divided into two portions by a circular contraction, and the stomach of ruminating animals is divided into four parts, the three first of which communicate with the œsophagus. The herbage when descended into the maw, imperfectly triturated by the masticatory organs, the power of which is very inconsiderable, there suffers the beginning of an acid fermentation: the contractions of this first stomach cause a small portion of it to pass into the second, which contracts on itself, envelops with mucus the aliment already softened in the first, forms it into a round mass, which reascends into the mouth by a true antiperistaltic motion of the œsophagus; the alimentary bolus, again masticated by the animal, which seems to enjoy this process, redescends through the œsophagus into the third stomach, called *feuillet*, on account of the large and numerous folds of its internal membrane: from this it passes into the last stomach, where the digestion is completed.

Some men have presented us with a kind of rumination. The aliment descends into the stomach, soon after returns into the mouth to suffer a second mastication, and to be again acted on by the saliva.—(See *Ant. Conrad. Peyer*, *Merycologia*, *sive de Ruminantibus.*)

Granivorous birds, particularly the class of gallinacei, have a double stomach. In the first, which has fine membranous coats, the grain softens, and suffers a sort of preliminary mastication, after which it is more easily broken by the action of the gizzard, a muscular stomach, that performs the office of the masticatory organs, of which this class of animals is absolutely destitute. The aliment, after having been divided by the successive action of the craw and the gizzard, passes into the duodenum, and when under the action of the biliary liquids, experiences changes that are the most necessary to the act of digestion.

The urinary bladder is deficient in the numerous class of flying birds; in them the ureters open into a muscular membranous sac, which supplies the place of the rectum, the bladder and uterus, and at the same time serves as a reservoir for solid excrement, urine, and eggs, detached from the ovaria. The urine of birds softens the fæces, and furnishes carbonate of lime, which forms the basis of the solid covering or shell of the egg; it has so great a disposition to concrete, that I have uniformly observed an earthy, or saline and crystallized matter forming white striæ, easily perceptible in the liquid that flows by the ureters through the fine transparent membranes of these ducts. My particular friend, M. Alibert, with whom I have had an opportunity of dissecting a number of birds of different species, ingeniously thinks that the calcareous matter that is so abundant in their urine, passes with the excrement of digestion, because it is to serve for the exterior covering of eggs; and, on the other hand, being contained in less proportion in their bones, it thus fulfils the intentions of nature, which must have formed them lighter as they were designed to inhabit the air.

CHAPTER II.

ABSORPTION.

XXVIII. IN the history of the phenomena of life, the explanation of the functions of the absorbent system ought to follow that of the functions of digestion. The vessels which receive the chyle, separated from the food by the action of the digestive organs, form a considerable part of the absorbent system, perfectly resemble the other lymphatics, and differ from them only in their origin. When digestion is not going on, these vessels carry a pure lymph absorbed from the intestinal canal, the internal surface of which, though empty, is always copiously moistened with a mucous serosity.

There exist in every part of the human body, in the interior as well as on the surface of our organs, vessels invested with the double occupation of absorbing and of carrying into the mass of blood certain substances, by means of which our machine supports and repairs itself, and the loss which results from the continual destruction of parts; for it should not be forgotten that organized, living matter, internally agitated by a double motion, compounds and decompounds itself continually.

XXIX. Absorption is less energetic externally than internally, or on the surface of the body than on the surface of internal cavities, and even in the substance of our organs. Cutaneous absorption has so little activity, under certain circumstances, that some philosophers have doubted of its existence. The vessels arising from the surface of the body have their absorbing orifice covered by the epidermis or cuticle. This insensible and inorganic medium forms a sort of barrier between the internal and external parts of the economy; prevents or renders more difficult the introduction of substances that are in immediate contact with our body; and if it be considered that we are often surrounded by gas or other substances, deleterious in a greater or less degree, we shall easily perceive how useful it is that the absorbent surface of the skin should not be entirely uncovered, and cutaneous inhalation thus rendered too easy.

The increase of weight in the body after a walk in damp weather; the abundant secretion of urine after remaining for some time in a bath; the evident swelling of the inguinal glands after long-continued immersion of the feet in water, an experiment often made on himself by Mascagni; the effects of mercury administered by frictions, &c. incontestibly prove that absorption is effected by the skin, under different circumstances, with more or less activity. We should observe, that the means which favour it, act, at least, as much in changing the structure of the epidermis as in augmenting the action of the absorbing orifice of lymphatic vessels: it is on this principle that baths seem to act, which soften it, and frictions which destroy the arrangement and elevate its superincumbent scales.

Absorption is performed with great celerity and ease in every part where the epidermis is fine and usually moist, the skin very delicate, and those parts, the under surface of which is almost uncovered, as the lips, the internal surface of the mouth, the glans penis, &c. It is also very active on internal surfaces; but there is no part which possesses greater energy than the intestinal canal; it is therefore in general the best way of introducing medicated substances into the body, and would always be so, were it not they underwent a change by their mixture with the gastric juices. The radicles from which the lymphatics arise have such minute orifices, that they cannot be perceived with the naked eye; the puncta lachrymalia being larger and more easily perceptible, give a just idea of them. Each orifice, endued with a peculiar degree of sensibility and power of contraction, dilates or contracts, absorbs or rejects according to the mode in which it is affected by substances that are applied to it. The variations of the power of absorption dependent on age, sex, temperament, different times of the day, &c. sufficiently prove that it cannot be compared, agreeably to the sentiments of some physiologists, to that power which causes liquids to ascend in capillary tubes, contrary to their own gravity; if absorption were a phenomenon purely physical, it would not be in any case either accelerated or retarded, and would proceed with a regularity unknown to vital actions. Each lymphatic absorbent, when disposed for absorption, erects, draws with it the surrounding membranous parts, and thus forms a small tubercle, analogous to those of the puncta lachrymalia. These minute projections, covered with the mucus of the intestines, have deceived Lieberkuhn, and induced him to believe that the lymphatics of the intestines arose from bubbles or vesicular swellings, which, like so many air-holes, absorbed the chyle extracted from the food. This physiologist has been likewise led into error by the nervous papillæ (swelled with blood, from the irritation produced by the friction of alimentary substances) on the internal membrane of this canal: the inhalent faculty is not totally confined to the orifices of the extremity of each of the radicles, but the lateral pores in the parietes of vessels equally possess that power.

XXX. After having arisen on the surface and in the substance of parts by very contiguous radicles, the lymphatics creep and take a serpentine direction; in forming many windings they join each other, then separate, and are again connected, and form, by these numerous anastomoses, a net-work of close texture, which, in conjunction with sanguineous vessels, constitutes the basis of the cellular structure of membranes.

Each lamina of cellular structure, according to Mascagni, is nothing but a net-work of lymphatic vessels; the basis of membranous pellucid structures, as the pleura, the peritoneum, resembles that of the lamina of cellular texture; and, finally, the same vessels form the principal part of mucous membranes, that are expanded over the internal surface of the primæ viæ, the lungs, and the urinary passages. The Italian anatomist has done well to distend with mercury all that structure which he considers lymphatic; but Ruysch, in his admirable injections, equally reduced membranes and adipose structure to a net-work completely arterial, the component parts of which, intimately connected, left a distance hardly perceptible by the microscope; and he drew from this preparation the following consequence: that the arterial capillary vessels divided, folded, and contorted in various directions, formed the basis of cellular laminæ and membranous structure. These results, so contradictory in appearance, prove that lymphatic vessels and capillary arteries enter into the structure of cellular laminæ and membranous texture.

Similar prejudices arise not only from the importance we wish to give to the pursuits in which we are particularly concerned, but also from the distention of the most minute vessels by the injection in their cavities, which being dilated to an unusual extent, compress parts situated in their vicinity or interstices, which disappear in consequence of this compression.

To convince ourselves that the pleura, peritoneum, &c. are not exclusively absorbent vessels, as Mascagni affirms, nor arterial, agreeably to Ruysch's opinion; it is only necessary to consider, that arterial exhalation and lymphatic absorption are carried on, at the same time, throughout the whole extent of internal surfaces; and that these two functions give us reason to believe the existence of both systems of vessels in membranes and in cellular structure.

Lymphatic vessels emerging from the cellular net-work unite into trunks large enough to be distinguished from the laminæ of that structure: these trunks take a direction towards certain parts of our body; there they unite to others, or continue parallel with frequent mutual communications. Lymphatic vessels do not pass on singly, as arteries and veins; but united they form fasciculi of various magnitudes, some of which, deep-seated, accompany sanguiferous vessels in all their distributions; while others, more superficial, correspond to the sub-cutaneous veins of parts, situated like them between the cutis and aponeuroses, and are most numerous on the inner side of the extremities, where they are more secure from external violence. The lymphatics of the parietes of large cavities form also two divisions, one superficial, the other deep-seated.

Their peculiar serpentine direction, their very numerous communications, and particularly their unequal diameter in different parts of their extent, also distinguish them from sanguiferous vessels. A narrow lymphatic often dilates so much as to equal the thoracic duct in diameter, then contracts, and in its passage again dilates without receiving any branch in the course of this diversity of magnitude. When all the lymphatic net-works are filled with mercury, our organs are entirely covered with it, and the whole body seems enveloped by a thread of narrow close laminæ. The passage of humours from one part to another very distant, seems easy of explanation to any one who has seen these numerous anastomoses made evident by injections. Metastases to him cease to be an inexplicable phenomenon; he will equally perceive without difficulty, that, by means of the lymphatics, all parts communicate together; that liquors absorbed by these vessels in one organ can be carried into another, and over the whole body, without passing through the circuitous course of the circulation; that liquids drunk may thus pass directly from the stomach into the bladder, and the chyle of the intestinal canal to the breasts; that pus can withdraw itself from the liver in which it was formed, to be carried to a part where irritation is prevalent, &c. Every thing that Bordeu has said of oscillations of the course of humours through cellular texture, in his *Recherches sur le Tissu muqueux*, is equally well explained by the anastomoses of lymphatic vessels.

A young man, for whom I had ordered frictions on the inner surface of the left leg and thigh to resolve a large bubo, was seized with a salivation the third day, although only half a drachm of ointment had been used each night. The salivary glands on the left side only were swelled, the left half of the tongue was covered with aphthæ; the right side of the body remained totally free from mercurial influence; an evident proof that the mercury had been carried along the left side of the body to the mouth, without passing into the circulation, or, perhaps, through any conglobate gland; for that in the left groin did not sensibly diminish in size. Salivation, therefore, in the treatment of the venereal disease, may take place without the mercury being carried into the circulatory system; which gives us reason to think that the phenomena of syphilitic affection, like the action of remedies used for it, chiefly take place in the lymphatic system.

XXXI. If the fluids absorbed by these vessels can pass, by means of their numerous anastomoses, through all the parts of the body without being mixed with the mass of blood, not a single drop can enter the circulation without having first passed through the glandular bodies situated in the course of lymphatic vessels, extending like them through every part; rarely existing alone, but in groups, as in the ham, the axilla, the flexure of the groin and fore-arm, by the side of the iliac vessels, the aorta and jugular veins, around the basis of the maxilla and the occiput, behind the sternum, along the internal mammary vessels, and in the substance of the mesentery, where their number and magnitude are in proportion to the quantity of absorbents that pass through them. These oval or globular bodies of a reddish colour, present two extremities, one of which is turned towards the part whence the lymphatics arise, which are inserted into them by a greater or less number of branches, that acquire the name of *vasa adferentia;* while these lymphatic vessels pass out larger, but less numerous, at the other extremity towards the thoracic duct, and from their use are called *vasa efferentia.*

The lymphatics, when in the glands, divide, reunite, and communicate together; they are, besides, interlaced, and form the structure of conglobate glands, which are nothing but an assemblage of vessels contorted and connected by cellular structure, in which sanguiferous vessels are distributed that give the red colour observed in these glands. The coats of lymphatic vessels are finer in the glandular structure than in other parts; their dilatations, divisions, and anastomoses are there more frequent. All the lymphatic vessels that are directed towards a gland do not penetrate its substance; some pass by the side, and, surrounding it, form a kind of plexus, the branches of which are directed to other glands nearer to the thoracic duct. The lymphatic glands form such an essential part of the absorbent system, they affect the lymph with such necessary changes, that no lymphatic vessel arrives at the thoracic duct without having passed through them. The same vessel often passes through several glands before it arrives at the common centre of the lymphatic system: it is in this manner that those which absorb chyle in the intestinal canal pass several times through the glands of the mesentery. The lymphatics of the liver, near the reservoir of Pecquet, have appeared to some anatomists to differ from the general law; but there constantly exist some glands in their passage: yet as they are in a very small number, the lymph brought from the hepatic organ is only once subject to glandular action; and this, in my opinion, explains in a satisfactory manner the passage of the colouring part of the bile, which in *icterus* evidently tinges the blood, and in which M. Deyeux has found it by chemical analysis.

XXXII. The parietes of lymphatic vessels are formed of two coats; both of them are fine, transparent, and yet very strong, since they support a column of mercury without bursting, which would lacerate arterial coats of equal diameter. The internal coat, which is thinner, gives rise to valvular plicæ, disposed in pairs like the valves of veins, and convenient, like the latter, to prevent the return of lymph towards the part from which it has been absorbed. Although these coats be very strong, elastic, and possess a great degree of contraction, since they have been seen to contract and propel the lymph with rapidity at the instant we open the abdomen or thorax of a living animal, the course of the lymph is far from being as prompt as that of the blood; it seems even to be frequently subject to vague, uncertain oscillations, like those of the blood in the capillary arterial net-work. The dilatations, curvatures, and numerous anastomoses of vessels, must particularly retard its progress; but it is chiefly in the structure of glands that it experiences a considerable retardation, for the lymphatics are there more peculiarly contorted, have dilatations, divide, and mutually communicate; and in these parts their coats are finer, for we find glands are lacerated by the weight of mercury, to which the vessels in other parts make sufficient resistance; and their action, which is naturally weaker, is still diminished by close cellular adhesions that unite those vessels, the assemblage of which constitutes a glandular body.

In some cases the energy of absorbent vessels seems much augmented. On this principle we have seen a jaundice rapidly succeed to a wound of the liver; and in other cases, metastasis, or the removal and deposition of humours, take place with extreme rapidity. I then suspect that the obstructed matter circulates by means of the anastomoses, and passes through the lymphatic net-work, with which the whole body and each individual part is surrounded, without traversing the glands, which would have retarded its course, and effected a greater or less alteration in its nature.

It was necessary for the course of the lymph to be retarded in its passage through the glands, in order to undergo all the changes to be effected on it by these organs. Although it be not known precisely in what these alterations consist, it may be said that their object seems to be to occasion the most intimate mixture, the most perfect combination of its elements, to impress on it a certain degree of animalization, as proved by the greater *concrescibility* of lymph taken from the *vasa efferentia*, or those which pass from glands, to deprive it of more heterogeneous principles, or at least to alter them, that they may not become hurtful in passing into the mass of humours. The yellow colour of the glands, in which the lymphatics of the liver ramify, the black colour of the bronchial glands, the redness acquired by the mesenteric glands of animals that are made to eat madder, beet-root, &c. &c. prove that the glands secrete, or have a tendency to secrete the colouring

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part of the lymph; and if they do not prevent the passage of this element into the blood, it is because certain colours, as those of indigo and madder, have too much tenacity, while other substances, as the bile, do not pass through a sufficient number of glands to be totally deprived of it. The sanguiferous vessels are very numerous in the structure of conglobate glands, and exudate a serosity on the internal surface of the lymphatics, which dilutes the lymph, increases its quantity, and at the same time impresses a degree of animalization.

It is to the long residence of the lymphatic fluid in conglobate glands, to the relative weakness of the vascular parietes in these parts, that we ought to attribute the frequency of their swellings. The action of debilitating causes on the lymphatic system particularly affects the glands, which are its weakest parts; the vessels that constitute their structure then become languid, or entirely cease to act; the fluids continually conveyed accumulate; the most fluid part only passes through the glandular organ; the grosser particles remain; the humour inspissates, indurates, and forms various kinds of swellings. If a cancerous disposition exist, these tumours, at first indolent, become painful; the indurated substance being to a certain degree beyond the sphere of vital activity, since the vessels are in a complete atony, suffers a kind of putrid fermentation, the product of which destroys and corrodes the glandular structure, and excites inflammation of the skin and surrounding parts. The tumour becomes an abscess; a liquid matter flows from it by the putrefactive motion, so acrid and irritating, that it propagates the infection towards every part with which it comes into contact.

The different terminations of glandular swellings of a cancerous, scrofulous, venereal nature, &c. authorize the presumption of specific ferments, or virus, which dispose the accumulated matter to contract such or such a kind of alteration.

The syphilitic virus, absorbed by the lymphatics of the genital parts, remains some time in the glands of the groin before it is carried farther, as proved by the cure of the lues venerea, by the removal of these diseased glands. Finally, the retardation suffered by the lymph in passing through these glands, explains the cause of these parts being so often the seat of critical depositions, by which are discovered several fevers of a bad type. In the eastern plague, the virus that occasions this terrible malady, disseminated throughout the whole body, collects in the glands, passes them with great difficulty, irritates them, and induces gangrenous inflammation, by which pestilential buboes terminate.

XXXIII. The thoracic duct may be considered, perhaps, as the centre or general boundary of the lymphatic system; it arises on the superior part of the abdomen, from the union of the chylous vessels with the lymphatics, which come from the inferior extremities. At the part where all these unite, it frequently offers a dilatation like a bubble, which has been called *receptaculum chyli*, or of Pecquet: this does not always exist, and is very variable in magnitude. The thoracic duct enters the chest by passing through the aortic perforation of the diaphragm, then ascends the length of the dorsal vertebræ, on the right side of the aorta, in the substance of the posterior mediastinum. When ascended near the upper part of the thorax, about the seventh vertebra of the neck, it makes a curvature from the right to the left, passes behind the œsophagus and trachea, and opens into the left subclavian vein, on the posterior part of the insertion of the internal jugular into this vein. In thus ascending the dorsal vertebræ, the thoracic duct receives the lymphatics of the parietes of the chest; those of the lungs are inserted when it passes behind the root of these organs; at the part it makes the flexure towards the left, those of the right superior extremity, and of the right side of the head and neck, join, and ultimately unite to those which come from the left side of the head and neck, as well as the left superior extremity, when it is about to open into the subclavian vein. Sometimes its insertion is into the jugular vein of the same side; the lymphatics of the right side of the chest, of the neck, head, and right superior extremity, occasionally unite to form a second canal, which has a separate insertion into the right subclavian vein. Whatever be the vein into which this canal opens, its structure is the same as the lymphatics, and its internal surface is furnished with valvular plicæ; its size does not augment progressively as it approaches the termination, but, on the contrary, it offers different dilatations, separated by successive contractions of its diameter: sometimes it is divided into two or more vessels, which anastomose and form a lymphatic plexus.

The orifice by which the thoracic duct opens into the subclavian vien, is furnished with a valve, better accommodated to prevent the passage of the blood into the lymphatic system, than to moderate the too rapid entrance of the lymph into the circulating mass. (See Sabatier, Remarques sur le Canal thoracique.)

The compression of the thoracic duct in aneurisms of the heart and aorta gives rise to several species of dropsy, an affection most frequently occasioned by an obstruction of glands, through which the lymph cannot pass.

XXXIV. The lymph still remains far from being so well known as the vessels in which it circulates. Haller considers it very analogous to the serum of blood, and says, that, like this serosity, which he often calls lymph, the liquid which flows into the system of absorbents is lightly viscous and saline; that it is coagulable by heat, alkohol, and acid: in fact, he assigns to it all the qualities of albuminous humours. The serum of the blood exhaled throughout the whole extent of internal surfaces, even in the texture of our organs, by capillary arteries, and absorbed by the lymphatics, is one of the principal sources of lymph, which should have the greatest resemblance to it; yet we can conceive that the nature of the latter ought to be more compound than that of the serum of blood, since the lymphatics, almost equally active in every kind of absorption, inhale, in every part of the body, the *detrita* of our organs, and the excrementitious part of our humours, sometimes distinguishable in the lymphatic vessels, as adeps, not miscible in aqueous fluids, bile of a deep yellow colour, &c. &c.

The chyle, on the peculiar properties of which the various kinds of aliment have a necessary influence, is not entirely alike in individuals that absorb nutrition from different substances; it receives a blue tint from indigo (Lister, &c.), a red from madder and beet-root, a green from the colouring part of several vegetables, &c. It has always appeared to me, in a great number of experiments made on living animals, just as authors describe it, white, lightly viscous or tenacious, and very much like milk in which a small quantity of flour has been mixed: its taste is sweetish, sometimes as if lightly sugared, and very analogous to milk.

Hallé, who procured a certain quantity of it, has found that the chyle exposed to the air, at rest, when cooling separates into two parts, one forming a sort of gelatinous coagulum, very fine, and analogous to the cup of inflammatory blood; the other more abundant and liquid, which ascends above the coagulum when detached from the sides of the capsule to which it adheres. The coagulated mass is semitransparent, lightly red, does not resemble the curd of milk; so that every thing that has hitherto been said by physiologists on the pretended exact similitude that exists between milk and chyle, is destitute of foundation.

The lymph, which is always mixed with the chyle before the latter is poured into the sanguineous system, when received into a vessel, by Mascagni, concreted within the space of from seven to ten minutes, acquired a sour odour, and soon separated into two parts; one was in greater quantity and serous, in the middle of which floated a fibrous coagulum, which in contracting formed a small cake on the surface. He draws a conclusion from it contrary to the opinion of Hewson, that serum constitutes the greater part of the lymph, and that the fibrous part is only its smaller portion.

XXXV. The practice of surgery in a great hospital has furnished me with frequent opportunities of examining the lymph, which flows copiously from ulcerated scrofulous tumours in the groin, the axilla, and in various parts of the body. I have always found it to be a liquor almost transparent, a little saline, coagulable by heat, alkohol, and acids; small fibrous *flocculi* form even on the surface of linen that imbibes it, and indicate the existence of two parts; one is a gelatino-albuminous fluid, containing different salts in solution; the other, smaller in quantity, is a fibrous substance spontaneously concrescible. In fact, lymph in man and animals of warm blood seems to be very analogous to the fluid which flows in the vessels of white-blooded animals.

CHAPTER III.

ON THE CIRCULATION.

XXXVI. WE call by the name of circulation that motion by which the blood, going from the heart, is continually carried into every part of the body by the arteries, and returned by the veins to the centre from which it was first propelled.

A circular motion is necessary to bring this fluid, changed by the admixture of lymph and chyle, into contact with the air in the lungs (respiration), to carry it to several of the viscera, which cause it to pass under different degrees of depuration (secretions), and to propel it towards the organs: its nutritive, animalized, and perfected part, in consequence of these successive actions, is employed for growth, or the reparation of continual loss (nutrition).

The organs of the circulation do not serve so much for the elaboration, as for the passage of the humours. To form a just idea, we may compare them to those porters who are employed in an extensive manufactory, from which proceed various species of produce, to carry materials to the workmen engaged in the manufacture; and as there are, among the latter, some who finish and complete the work which others had begun, so the lungs and secretory glands are incessantly employed to separate from the blood every thing that is too heterogeneous to our nature to become a proper object of our organs, to be assimilated into their own peculiar structure, or to afford nutriment.

To understand with accuracy the mechanism of this function, it is necessary to study the action of the heart, of the arteries which proceed from it, and of the veins returning from it, separately; it is from the union of these three kinds of organs that the circulatory system is composed.

Action of the Heart.

XXXVII. In man and all animals of warm blood, the heart is an hollow muscle, the internal part of which is divided into four large cavities which communicate together, whence arise the vessels that carry the blood into every part of the body, and in which those vessels terminate which return the blood from every part. It is situated in the chest between the lungs, above the diaphragm, and influenced by all its motions; surrounded by the pericardium, a fibrous, dense membrane, possessing little extensibility, closely connected to the substance of the diaphragm, reflected over the heart and its large vessels without containing them in its cavity, furnishing the heart with an external covering, and moistening its surface with a serosity that never accumulates except in cases of disease, but facilitates its motion, and prevents an adhesion to parts in its vicinity. The principal use of the pericardium is to retain the heart in its proper situation, to prevent it from being carried into different parts of the thorax, which would occasion fatal derangements of the circulation. If we make an incision into the pericardium of a living animal, in detaching the sternum, after having opened the chest, the heart leaps out of its sac through this aperture, and falls on the right or left side of the thorax, pressing on the large vessels; the circulation of blood is then prevented, and the animal is threatened with speedy suffocation.

The comparative size of the heart is more considerable in a fœtus than an infant, in short persons than in those of taller stature. It is not exactly oval in man, as in the generality of animals.

Neither is it parallel to the spine, but obliquely situated, and flattened towards the side connected with the diaphragm, on which it rests.

Of the four cavities which constitute the heart, two are, in some measure, accessory: these are the auricles, small muscular membranous sacs, which receive the blood from the veins, and pour it into the ventricles, to the base of which the auricles are attached. The ventricles are two muscular sacs, separated by a partition similar to that between the auricles: they form the principal part of the heart, and from them arise the arteries.

The right auricle and ventricle of the heart are larger than the left auricle and ventricle; but this difference of size is as much dependent on the manner in which the blood circulates on the approach of death, as on the primary conformation of that organ. Towards the last sigh the lungs dilate with difficulty, and the blood propelled into them by the contractions of the right ventricle, not being able to pass through them, accumulates in this cavity, returns into the right auricle, to which the veins also continually carry blood, separates its parietes, and particularly increases its volume. The capaciousness of the right cavities of the heart is, however, greater originally than that of the left: it is in relative proportion to the venal system, of which it is the reservoir. The right cavities of the heart, which may also be called the venous cavities, have thinner parietes than the left or arterial cavities, and in this the same difference as exists between the coats of veins and of arteries may be observed; besides, the right ventricle having to propel the pulmonary blood through a short course, and of a structure easily permeable, had only occasion to communicate a weak impression.

Several anatomists have particularly attended to the structure of the heart: much has been said on the arrangement of the muscular fibres that enter the composition of its parietes; yet the only result that can be drawn from these labours is, that it is impossible to explain its intricacy. The common fibres variously interlaced form the two auricles; others, more numerous, constitute the parietes of the ventricles, elongate from the apex towards the base, are inserted into the part which separates the ventricles from each other, and are lost in certain parts of its substance. They are extremely red, short, compact, and united by cellular texture, in which adeps is very rarely collected.

When forcibly pressed against each other, they form a structure analogous to the fleshy body of the tongue, not very sensible, but possessing a great degree of irritability and contractility. The nerves and vessels entering this muscular structure are very numerous in comparison of the size of the heart; and their contraction, whatever be the direction of fibres, tends to approximate every point of the parietes towards the centre of the cavities: a very fine membrane lines the inner surface of these cavities, facilitates the passage of the blood, and prevents its escape into the substance of the heart.

XXXVIII. Admitting for a moment that all the cavities of the heart are perfectly empty and full successively, the following is the mechanism of its circulation: the blood brought from every part of the body is poured into the right auricle by the two *venæ cavæ*, and the coronary vein separates its parietes and dilates in every part. The right auricle, irritated by its presence, contracts; the incompressible fluid returns partly into the veins, but chiefly passes into the pulmonary or right ventricle through a large aperture, by which it communicates with the right auricle. The right auricle, after being thus liberated from the blood which distended it, relaxes, and admits of repeated dilatation by the access of more fluid, which the veins are continually pouring into it.

The right ventricle is distended with the blood received from the auricle, the presence of which irritates its parietes, and causes it to contract; the blood has a tendency from this contraction to return into the auricle, and to pass into the pulmonary artery: the reflux into the auricle is prevented by the tricuspid valve, a membranous ring surrounding the aperture of communication; its loose extremity is divided into three parts, to which are attached the small tendons terminating several of the *carneæ columnæ* of the heart. They remain closely applied to the parietes of the ventricle, when the blood enters that cavity; but when it contracts they separate from it, and are carried towards the auricular aperture. They cannot be protruded into the auricle, since their loose, flowing edges are attached to the carneæ columnæ, that should be considered as so many small muscles, of which the tendons are destined to retain the loose edges of the valves; to which they adhere when the efforts of the blood have a tendency to force these membranous folds into the auricles, yet as they do not completely close the aperture, and their substance has several small orifices, a part of the blood returns into the auricle; but it passes in greater quantity into the pulmonary artery. This vessel begins to act when the parietes of the ventricle relax, and would drive back the blood if the three sigmoid valves did not impede its return. The blood, supported by a kind of partition made by the falling of these valves, passes through the structure of the lungs, and all the divisions of the pulmonary vessels, from the arteries into the veins, which latter are four in number, and pour it into the left auricle. This receptacle, stimulated by the presence of the blood, contracts in the same manner as the right auricle; some of it returns into the lung, but the greater portion is carried into the left ventricle, which propels it into the aorta and through every part of the body by the arteries, and it returns to the heart by the veins. The return of the blood into the auricle is prevented by the mitral valve, completely analogous to the tricuspid, and merely differing from it by having only two loose edges. When in the aorta this vessel contracts; its semilunar valves fall, and the blood is propelled into every part of the body through the innumerable ramifications of the great artery.

In a natural state, the events do not take place as thus described, and a successive action of the four cavities is only adduced to elucidate the mechanism of the circulation through this organ. If we demonstrate the fact in a living animal, we find that both auricles contract at the same instant, and that the contraction of both ventricles, is also simultaneous; so that when the auricles contract to drive out the blood which distends them, the ventricles dilate to receive it: this succession in the contractions of the auricles and ventricles, is easily explained by the successive application of the stimulus producing them. The blood returned by the veins into the auricles does not excite the irritability of their parietes until it be accumulated in sufficient quantity; while this accumulation is forming they are compressible, and the resistance made to the finger during their dilatation depends entirely on the presence of the blood, which distends and supports them. It is just the same with the ventricles; in order for them to contract, it is necessary that the blood be collected in sufficient quantity; the small portion of this fluid remaining in these cavities, which never completely empty themselves, cannot form an objection to this theory, for this is not sufficient to induce a contraction, and ought not to be an object of consideration.

If it be asked why the four cavities of the heart do not contract at once, it is more easy to give a reason for it than to determine its proximate cause. If the contraction of these cavities had been simultaneous instead of successive, we can easily perceive that the auricles could not have emptied themselves into the ventricles; besides, an intermission of action is absolutely necessary, since the heart, like other organs, cannot continue in perpetual action; the principle of its motions is soon exhausted, and only restored by repose; but the alternate states of motion and rest in those organs which, like the heart, perform functions essential to life, ought to be extremely short and frequent, as mentioned in the beginning of this work on vital powers and functions.

XXXIX. The heart evidently shortens; its base approaches its apex during the *systole* or contraction of the ventricles. If it elongated, as several anatomists have believed, the tricuspid and mitral valves could not answer the purposes for which they were destined, since the carneæ columnæ, the tendons of which are attached to their edges, would keep them applied to the parietes of these cavities. The palpitation perceptible in the space separating the cartilages of the fifth and sixth ribs on the left side, is occasioned by the apex of the heart striking against the parietes of the thorax. To explain this phenomenon, it is not necessary to admit of elongation of the heart during the systole; it will be sufficient to consider that its base, where are situated both auricles, is resting on the spine; and that these two cavities, dilating at the same time, and unable to depress the bone, push the heart downwards and forwards: this motion as also a dependence on the effort made by the blood, propelled into the aorta to obliterate the parabolic curvature of this artery, which reacts, and carries downwards and forwards the entire mass of the heart, which is apparently suspended to it.

The quantity of blood that each contraction of the ventricles projects into the aorta and pulmonary artery, can hardly exceed two ounces for each of these vessels. The force with which the heart acts on the propelled fluid is not well known, however numerous may have been the methods of calculation applied to the solution of this physiological problem: from Keil, who only estimated the power of the heart at some ounces, to Borelli, who carries it to 180,000 pounds, we find the calculations of Michelot, Juvine, Robinson, Morgan, Hales, Sauvages, Cheselden, &c.; but, as Vicq d'Azyr observes, there are none of these opinions which are not erroneous, either in anatomy or calculation; whence we may conclude with Haller, that the force of the heart is great, but that it is impossible to be estimated with mathematical precision. If we open the chest of a living animal, pierce the heart, and introduce the finger into the wound, we find its extremity strongly pressed during the contraction of the ventricles.

Those who have rigorously admitted Harvey's doctrine relative to the circulation of the blood, and believed, as he did, that the heart was the only agent, have exaggerated the force of this organ to make it equal to the length of the passage which the blood has to pass through, and the multitude of obstacles in its course: but we shall presently observe, that blood-vessels ought not to be considered as inert tubes, in which the fluid flows merely by the propulsion communicated to it by the heart.

Action of Arteries.

XL. There is no part of the body into which the heart does not send blood by means of the arteries, since it is impossible to thrust the finest pointed needle into the structure of our organs without wounding several vessels, and occasioning an effusion of blood. We may compare the arterial aortic system to a tree, the trunk of which, represented by the aorta taking root in the left ventricle, spreads its branches to a great distance, and sends to every part numerous ramifications. Arteries diminish in size in proportion as they are distant from their trunk or origin; yet their form is not conical, but rather like cylinders proceeding from each other, which successively diminish in magnitude. As the branches produced from a trunk, taken collectively, present a greater diameter than the trunk itself, the capaciousness of the arterial system augments in proportion as it is distant from the heart; whence it follows that the blood, always passing from a narrower into a wider space, should be retarded in its passage. Their direction is often curved; and we observe that arteries distributed on the parietes of hollow viscera, as the stomach, uterus, bladder, or other parts susceptible of contraction, alter their dimensions every instant: the lips present us with an example of the greatest and most numerous curvatures, doubtless to accommodate themselves to the extension of the part in which they are distributed. In fact, arteries arise from each other in forming with the trunk, branch, or ramification which produces them, an angle of various magnitude, always obtuse on the side of the heart, but more or less acute towards the branch.

Arteries in extending from their origin communicate together, and these anastomoses are made sometimes by an arch, two branches inclined towards each other, and connected at their extremities, as in the vessels of the mesentery; at other times they run parallel, and unite in a very acute angle to form one trunk: thus the two vertebral arteries unite to form the basilary; others communicate by transverse branches, passing from one to the other, as seen on the inside of the cranium.

In anastomoses of the first kind, the columns of blood flowing in a contrary direction in both branches strike at the point of union, mutually repel each other, and lose a great part of their motion in this reciprocal concussion; after this the blood takes a middle direction, and passes into the branches that rise on the convexity of these anastomosing arches.

When two branches unite to constitute a new artery of a larger diameter than each individually, but smaller than both collectively, the motion of the blood is accelerated, since it passes from a wider into a narrower channel, and the powers which occasioned its progression unite into one only: transverse anastomoses, indeed, are very necessary to facilitate the passage of the blood from one branch to another, and prevent the distention of parts.

XLI. The arteries, enveloped more or less in cellular structure, mostly accompanied by veins, lymphatic vessels, and nerves, have thicker coats in proportion to the diminution of their diameter. The experiments of Sir Clifton Wintringham prove that the strength of the parietes is more considerable in small than in large arteries; it is also observed, that aneurismal dilatations are much less frequent in them. These parietes have sufficient firmness not to be compressed when the arterial tube is empty. Three coats constitute their structure; the external is cellular, very extensible, and seems to be formed by the most intimate connexion of the laminæ of cellular texture which surrounds the artery and connects it with neighbouring parts; the second is thicker, more compact, yellow, and fibrous, and considered by some as muscular and contractile, while other physiologists only admit that it possesses great elasticity: the longitudinal fibres, described by some authors in the texture of the second coat, cannot be perceived; and to explain the retraction of arteries with respect to their length, it is not necessary to admit it; for this retraction might not only depend on elasticity, but also be the effect of retraction of fibres which are neither completely circular nor exactly transverse, but rather spiral, that imperfectly surround the vessel, the extremities of which variously cross each other. This yellow coat, proportionably thicker in ramifications than in branches, and in the latter than in trunks, is dry, hard, little extensible, and breaks by an effort to which the external coat accommodates itself by elongating. The third coat is fine, lines the internal surface of these vessels, and does not seem so much designed to increase the power of the parietes as to facilitate the course of the blood, by presenting a smooth, polished surface, continually moistened by a serosity exhaled from very minute arteries (vasa vasorum) which are distributed in their substance.

Besides these coats the large arteries have a fourth from the membranes that line great cavities: thus the pericardium and pleura in the thorax, and the peritoneum in the abdomen, furnish different parts of the aorta with an accessory covering, which is not extended over the whole circumference of this vessel.

XLII. The contractile force which arteries possess resides in the yellow or middle coat; it is so much the greater in proportion to its thickness, relative to the diameter of the artery. Thus, as Hunter observes, in his Treatise on the Blood, Inflammation, &c. the elastic is almost the only power with which the parietes of large arteries are invested, while irritability is very apparent in those of smaller diameter, and almost exclusively predominates in capillary vessels: thus the passage of blood into the large trunks in the vicinity of the heart, is principally occasioned by the propulsion communicated by this organ, and the circulation in the large vessels, as mentioned by Lazarus Riverius, is rather an hydraulic than a medical phenomenon; but in proportion as it becomes distant from the centre, several causes retard it, and the blood could not arrive at every part, were not the arteries, which are more active in proportion to their smallness and distance from the heart, to act, and propel it towards all the organs.

The causes which retard the course of arterial blood are, the increase of space, in which it is contained; the resistance made by the curvatures of vessels; the friction it suffers, which becomes more considerable as the vessels at a distance from the heart are more numerous; and likewise the deviations it must experience in passing from trunks into branches, which are sometimes sent off at almost right angles, interrupt its primary direction.

The reaction of arteries on the blood which dilates them does not only depend on the great elasticity that their parietes possess, but also on the contractile force of the muscular coat. Elasticity is of great consequence in the contraction of the larger trunks, while irritability almost alone occasions the contraction of the smaller arteries. If the finger be introduced into the artery of a living animal, we perceive it pressed by the parietes which closely embrace it; if the blood be prevented from flowing, the canal is obliterated by the approximation of its parietes, and the vessel degenerates into a ligamentous chord, like that which takes place in the adult in the umbilical vessels. This contractility, always in a state of activity during life, keeps the arteries distended by the blood which fills them, but of a less diameter than that which is found after death. In the practice of the great operations of surgery, particularly amputation of the extremities, I have constantly found the arteries, whether full or empty, much smaller than I had conceived from the appearance on dead subjects.

XLIII. As the arteries are always full during life, and the blood flows with so much the less rapidity as they are at a greater distance from the heart, that portion of this fluid which the contraction of the left ventricle propels into the aorta, coming into contact with the antecedent columns, communicates to them the impulse received; but being retarded in a direct passage by the resistance opposed, it acts against the parietes of vessels, and extends them on their axis. This lateral action by which the arteries are dilated, depends therefore on their cavities being always filled with a fluid which resists that projected by the heart. This dilatation, more considerable in larger arteries than in those of smaller diameter, is evident by a beating known by the name of the pulse; the experiments of Lamure, &c. give us reason to believe that a second cause of this phenomenon is a small change of situation which arteries suffer at the time of dilatation. These changes of situation are particularly observable at their curvatures, and where they adhere by loose cellular structure not closely connected to the surrounding parts.

The pulse is more frequent in children, women, persons of short stature, of strong passions of the mind, and those who undergo violent bodily exercise, than in an adult man of tall stature, serene mind, and quietude. In the first years of life it beats as much as 140 strokes in a minute, but as we advance in age the circulatory motion is retarded, and towards the end of the second year the pulse is only 100 in the same space of time. At puberty 80 pulsations in a minute are usual, about virility only 75, and in elderly persons who have attained their sixtieth year, the pulse is reduced to 60. The inhabitants of cold countries have a slower pulse than those of warm climates, &c.

From the time of Galen, the pulse has offered to physicians one of the principal means of distinguishing diseases, The force, regularity, equality of its motions, contrasted with its weakness, inequality, irregularity, and intermission, enable us to form a judgment of the kind and magnitude of a disease, of the powers of nature to effect a cure, of the organ particularly affected, of the time or period of the complaint, &c. No person has employed himself more successfully than Bordeu, on the doctrine of the pulse, considered in these points of view; his modifications indicative of the periods of disease, establish, in the opinion of this celebrated physician, as may be seen in his *Recherches sur le Pouls par Rapport aux Crises*, the pulse of crudity, of irritation, and of coction. Certain general characters indicate whether the affection occupy a part situated above or below the diaphragm; and from this is formed the distinction of superior and inferior pulses; and, lastly, peculiar characters denote the injury of each individual organ which constitutes the nasal, guttural, pectoral, stomachic, hepatic, intestinal, renal, uterine pulses, &c.

XLIV. At the instant the left ventricle contracts to propel the blood into the aorta, the sigmoid valves of this artery are elevated, and applied to its parietes without closing the orifice of the coronary arteries, which are situated above their loose edge, so that the blood passes into them at the same time as into the other vessels. When the ventricle ceases to contract, the aorta reacts on the blood, dilating it, and would return it into the ventricle if the valves did not suddenly descend to form an insurmountable obstacle, and become the basis of support for the action of all the arteries: the small quantity of blood found below the valves at the instant they descend is the only part which flows back towards the heart, and is returned into the ventricle.

Although the velocity of the blood flowing into the aorta has only been estimated at about eight inches in a second, the pulsatory motion is perceptible in every artery of a certain diameter, at the same instant in which the ventricle contracts. If the palpitations of the heart seem to be synchronous with pulsations of the arteries, it is because the columns of blood which distend these vessels are all struck together by that which goes from the ventricle, and that this concussion is transmitted to them in a moment; the blood which fills a principal trunk furnishes to each of its branches columns of blood of a magnitude proportionable to their diameter: this division of the principal column is effected by a small protuberance at the orifice of each artery. These internal projections detach from it small streams which pass so much the more easily into the branches as they arise at more acute angles, and the deviation of the fluid from its course is less considerable; if the branches go off nearly at right angles, the orifice is almost deprived of this internal projection, and nothing assists the passage of blood into them but the efforts of lateral pressure.

The course of the blood is not intercepted in the arteries which pass through muscles when they contract; for in every part where the arteries of a certain diameter are situated in their substance, they are surrounded by a tendinous ring, which enlarges when the muscle contracts, drawn in every direction by the fibres attached to its surface. It is easy to convince ourselves of this truly admirable arrangement, by examining the aorta at its passage between the crura of the diaphragm; also the artery which goes towards the thigh, as it passes into the posterior part of this extremity, when perforating the adductores, and the popliteal artery, in traversing the superior extremity of the solaris muscle, &c.

Capillary System.

XLV. The arteries, after having divided into branches, these branches into others, and again into still smaller ramifications, terminate in the structure of our organs by being continued into veins. The venous system, therefore, arises from the arterial; the origin of the veins is, then, only from the most minute extremities of arteries, which are become capillary from the great number of divisions, and return upon themselves with a change of structure.

> The number of arterial divisions that can be anatomically demonstrated, does not exceed eighteen or twenty; yet they subdivide even when so small as not to be discovered with the assistance of the most powerful microscope.

The capillary arteries, winding in a peculiar manner in conjunction with the veins, which are only a continuation of them, and with the lymphatic vessels, form a surprising net-work in the texture of our organs.

Several physiologists consider the capillary arteries as an intermediate system between the arteries and the veins, in which the blood, being absolutely beyond the influence of the heart, flows slowly, appears subject to oscillatory, sometimes even retrograde motions, and is no longer of a red colour, because the red globules are strained and lost in the serum they convey, which is destitute of redness. The irritability and sensibility in capillary and serous vessels are much greater than in veins and arteries; vitality must necessarily be more active in them; for the degree of motion impressed on the blood by contractions of the heart is obliterated: this fluid being out of the sphere of activity of that organ, can only circulate in consequence of vascular action.

There is but one origin of veins at present well attested, which is from the termination of arteries; this can be seen by the assistance of the microscope in animals of cold blood, as the frog and salamander. In some fish we can even discover with the naked eye large and numerous anastomoses between arteries and veins; but in man, as in all animals of warm blood, these communications only take place at the extremities of both systems. Arteries sometimes end in serous capillary vessels, as observed in the sclerotic coat of the eye; these vessels become small veins, the diameter of which successively augments until they admit red globules, united in sufficient number to reflect that colour. Under other circumstances the artery is continued into the vein without that minute division; red blood then passes with ease from one vessel directly into the other.

We shall see, in treating of secretions, that the continuation of arteries with the excretory ducts of conglomerate glands, and their termination in exhalant orifices, ought not to be admitted; and that lateral pores, with which the parietes of small arteries and veins are perforated, are adequate to explain the phenomena on which these terminations of arteries have been established. There does not exist any parenchyma, any spongious texture between their extremities and the commencement of veins, if we except the corpora cavernosa of the penis and clitoris, the bulbous and spongy part of the urethra, the *plexus retiformis* surrounding the entrance of the vagina, and perhaps also the texture of the spleen, although the experiments of Lobstein seem to prove that there exists in the last organ an immediate continuation between veins and arteries.

The action of Veins.

XLVI. The vessels, employed to bring back to the heart the blood distributed to all the organs by the arteries, are much more numerous than the latter. We find, indeed, that arteries of a moderate size, as those of the leg and fore-arm, have each two corresponding veins, the diameter of which is at least equal to their own; and that there is also an order of superficial veins situated between the cutis and aponeurosis that invests the muscles of a limb, which have no analogous arteries: the space in which the venal blood is contained is, therefore, more considerable than that occupied by arterial blood. Thus it is estimated that out of twenty-eight or thirty pounds of this fluid, which is about the fifth part of the entire weight of the body in an adult man, nine parts are contained in the veins, and four only in the arteries.

When this estimation is made, we must consider the blood of the pulmonary veins and left cavities of the heart as arterial, while that distending the right cavities of the heart and pulmonary artery constitutes a part of the venous blood, and has all its marked characters.

Veins are not only more numerous, but also larger and more capable of extension than the arteries: this was rendered necessary by the slowness with which the blood flows in them, and the facility of its retention when the smallest object retards its circulation.

The arteries mostly contain the same quantity of blood. Plethora always takes place in the veins, because in them the stagnation of blood is easier; and this state does not occasion inflammatory fever (which is only increased action of the vascular system, as expressed by the name *angeio-tenique*, adopted by Professor Pinel), until the sanguineous congestion is carried to a very high degree in the veins; the blood then can only pass with difficulty into these vessels. The heart and arteries, therefore, redouble their efforts to exonerate themselves from the distending fluid, &c.

The force which causes the blood to flow in the arteries is so great, that nature seems to have neglected the mechanical advantages that could have facilitated its course; on the contrary, the circulatory powers that determine the passage of venal blood have so little energy that nature has carefully removed every obstacle that could have impeded its return. Thus the relative connexion of smaller with larger branches, and of these with the trunk, being the same as in the arteries, two branches unite to form a vein larger than each taken separately, but smaller than their aggregate diameter: the blood flows in a space become narrower in proportion as it approaches the heart; its progress must consequently be proportionably accelerated.

The veins observe nearly a straight direction; at least their curvatures are less numerous and evident than those of arteries: the force causing the blood to circulate is not therefore employed to counterbalance these curvatures. Anastomoses are likewise more frequent; and as the course of the blood would have been intercepted in the deep-seated veins of a limb when the muscular masses, between which they are situated, become distended, rigid, and, by contracting, compress them, they have frequent communications with superficial veins, towards which the blood is carried, and there flows comparatively better on account of being free from compression; therefore the latter are very large and well marked in people who are employed in laborious work, in which their limbs are continually exerted; and, finally, the internal surface of veins, like that of lymphatics, is supplied with valvular folds from a duplicature of their internal coat. These valves are seldom alone, mostly disposed in pairs, are not to be found in large trunks, in very minute veins, nor in those returning the blood from viscera situated in great cavities.

When the valves are let down they completely close the canal, interrupt the column of blood returning to the heart, divide it into a number of small streams, equal to the diameter of the intervalvular spaces, the height of which is formed by the distance separating the valves; so that the moving powers of venous blood, which could not be sufficient to circulate the whole mass, are advantageously applied to each of the small portions into which it is subdivided.

XLVII. It has been believed that the principal cause of the passage of the blood in the veins was the combined action of the heart and arteries; but the propulsive force communicated by these organs is lost and obliterated in the system of capillary vessels, and does not extend to the veins: the action of their own coats, assisted by some auxiliary powers, as the motion of the neighbouring arteries, is sufficient to cause it to pass on to the heart.

The coats of veins are much finer than those of arteries, and enveloped in a cellular sheath like all other vessels. They are three in number: the middle or fibrous tunic does not exist in a very distinct manner, it is only manifested by some longitudinal red fibres, that are not perceptible but in the largest veins near the heart. In some large quadrupeds, as the ox, these fibres form visible fasciculi, and their muscular nature is more evident.

The internal tunic is as fine, but more extensible than that of arteries, and has a firm adhesion to the other coats; the cellular structure which unites it to the middle coat is not in such considerable quantity, therefore phosphate of lime is never deposited in it, as in arteries, which frequently ossify in advanced age. This internal coat is only a continuation of that which lines the cavity of the heart; and as the origin of the internal coat of arteries is the same, there exists an uninterrupted continuity in the membrane extended over the internal surface of all the circulatory canals.

In those parts where veins pass through the muscles, they are, like the arteries, protected by tendinous rings. None is more remarkable than that surrounding the aperture of the diaphragm, through which the vena cava ascendens passes from the abdomen into the thorax.

As the causes that induce venous blood to flow merely impress a tardy motion, and as this fluid encounters only weak obstacles easily surmounted, the pressure against the parietes of veins is inconsiderable, and these vessels have no pulsation analogous to that of arteries; yet in the vicinity of the heart an undulatory motion is communicated to the parietes of vessels. These kinds of pulsations alternately depend both on the rapidity with which the blood flows towards the heart, progressively accelerated, and the reflux experienced when the right auricle contracts: the contraction of this cavity pushes back the blood into the veins. This retrograde motion is manifest in the vena cava superior, as the orifice of this vein is not furnished with any valve that can prevent it; yet it does not extend far towards the brain, as the blood would be obliged to ascend contrary to its own gravity, and the jugulars are extremely capable of dilatation. This reflux is still better marked in the vena cava inferior, the orifice of which is imperfectly closed by the valve of Eustachius: it is perceptible in the abdominal veins, as far as the internal iliacs. This Haller says he has observed.

The orifice of the large coronary vein being exactly covered by the valve that is found near it, the blood does not return into the substance of the heart, a contractile organ, the irritability of which would have been diminished by the presence of venal blood. It is of some importance to remark, that the reflux of this liquid does not extend to the veins of a limb: their internal surface is supplied with valvular folds. It is not with the organs of motion as with secretory glands, towards which the momentum of the blood is retarded, in order to be longer subject to their action; the venous blood weakens, even destroys the irritability of muscles, and possesses a truly benumbing or stupifying property, as may be well demonstrated, either by injecting it into the arteries of a living animal, or preventing its return by making a ligature on the veins, or by attending to the events induced by an interruption of its course, by surrounding the limb with a tight dress or bandage.

I am convinced that it was on the observation of these oscillatory counterpoises of the venous blood in the largest vessels, that the ancients established their ideas on the course of the blood, which they compared to that of the river Euripus, the waves of which are represented by the poets to roll indiscriminately and follow contrary directions.

The internal veins, where this is observed, are those of the whole body, in which it is very easy to see the motion of the blood, their thin and semi-transparent parietes not being surrounded, as in other parts, with an adipose cellular texture. We shall form a complete notion of the doctrine of the ancients on the circulation, if we add to this idea the opinion they held of the chyle being received by the mesenteric veins and carried to the liver, in which sanguification was effected; and, lastly, that the arteries were filled with vital spirit, and only contained some drops of blood, which passed through several small orifices, discovered by Galen in the substance that separates the ventricles.

Yet the blood, continually propelled by the efforts of succeeding columns, by the action of veins, the parietes of which gradually become thicker, and by the compression that these vessels suffer from the viscera in the motions of respiration, ultimately arrives at the heart, and enters more easily into the right auricle, on account of the orifices of the venæ cavæ not being directly opposite to each other; the columns of blood they convey do not strike against each other, nor become a mutual obstacle.

XLVIII. The blood, continually carried to all parts of the body by the arteries, returns therefore to the heart by a motion that is never interrupted without danger of life: we are certain that circumstances take place in this manner by the disposition of the valves of the heart, of the arteries, and of the veins, from what happens when the latter vessels are opened, compressed, tied, or injected. If we open an artery, the blood that jets out of the wound comes from the side next to the heart; on the contrary, if a vein be wounded it comes from the extremities. The compression or ligature of an artery stops the course of the blood above the ligature; the vein, on the contrary, becomes distended below it: an acid liquor injected into the the veins coagulates the blood on the side nearest the heart. Examination by the microscope elucidates the continual passage of the blood from the heart into the arteries, and thence into the veins, which return it to the heart, in the semi-transparent vessels of frogs and other animals of cold blood. It was on this basis of irrefragable proofs, that Gideon Harvey, about the middle of the sixteenth century, established the theory of the circulation of the blood. The mechanism had been rather anticipated than explained by some authors; Servetus and Cesalpinus seem to have known it; but no person so clearly elucidated it as the English physiologist, and he is justly esteemed the author of this immortal discovery.

XLIX. The theory of Harvey, against which so many vain clamours were raised, does not seem to us admissible *in toto*. He considers the heart as the only cause of motion in the blood, and pays no regard to the action of arteries and veins, which he esteems to be inert tubes; whilst every thing tends to prove that arteries and veins assist the motion of the blood by an action peculiar to them. He admits that the celerity of the blood is uniform in all parts of the circulatory system; an opinion which reason and experience so evidently contradict, by proving that the velocity of this liquid diminishes in proportion as it is remote from the heart, by the influence of a multitude of causes that it would be needless to enumerate. (XLII.) There are, however, at present warm advocates for this opinion; and among the moderns, Spallanzani has endeavoured to support it with a number of experiments so contradictory, that it is surprising how such a judicious physiologist should have collected them to establish a doctrine so clearly refuted by others.

Plucking out the heart does not suddenly interrupt the action of vessels (Spallanzani); there are animals deprived of this organ that have vessels which contract and dilate by alternate motions. The nutritious juices of vegetables, like the lymph and chyle in man, flow entirely by the action of vessels. This, perhaps, would be the place to examine whether the heart and arteries possess a pulsative faculty, as Galen thought; that is, whether these organs dilate to admit the blood, or their dilatation be only a passive effect, induced by the presence of this fluid. I have repeated the celebrated experiment, without success, on which he pretends to establish this faculty; an artery tied and empty of blood constantly contracts, and is no longer affected by alternate pulsations. Many proofs, however, can be adduced in its favour, and the most convincing of them are those drawn from analogy, the lymphatics of animals, and the sap-vessels of plants.

If the powers of the heart alone propelled the blood through every part, the course of this fluid should be suspended at intervals; its circulation should be at least retarded when the ventricles cease to contract: but as the contraction of arteries coincides with the relaxation of veins, these two powers, the action of which is alternate, are continually exerted to push the blood into its innumerable canals.

Besides the general circulation, the laws and phenomena of which have been just explained, it may be said that each part has its particular circulation with greater or less celerity, according to the disposition and structure of its vessels.

Each of these peculiar circulations forms so many wheels in the great circulation, in which the course of the blood is variously affected, perhaps accelerated or retarded, without the principal circulation being influenced by it. It is from this cause that the radial artery may have an hundred pulsations in a minute in a panaris or whitlow of the finger, while that of the other side will only strike seventy, and those completely simultaneous with the action of the heart: thus the circulation of intestinal blood destined to furnish the bile, is evidently slower than that of other parts. (xv.) We shall see that it is equally retarded in the internal part of the cranium; but, on the contrary, accelerated in the lungs, &c.

These modifications that the blood suffers in the velocity of its circular motion, explain the difference of its qualities in various organs, all of which form the general plan of nature, and it is not difficult to point out their utility.

CHAPTER IV.

RESPIRATION.

L. OF all the changes the blood suffers in passing through our various organs, there are none more essential and remarkable than those occasioned by the influence of the air, which is alternately received into, and expelled from the lungs during the act of respiration. The blood which the veins return to the heart, and which the right ventricle sends into the pulmonary artery, is blackish and heavy; its temperature only 30 degrees of Reaumur's thermometer: if suffered to remain still, it coagulates slowly, and separates a great portion of serum. That which the pulmonary veins bring back to the left cavities of the heart, and which is conveyed into every part of the body by means of the arteries, is, on the contrary, of a red vermilion colour, frothy, lighter, and two degrees warmer; it is also more easily coagulable, and separates a smaller proportion of serum. All these differences, which are so easily perceptible, are dependent on the modifications arising from having been in contact with the atmospheric air.

In man and in all animals of warm blood, that have a heart composed of two auricles and two ventricles, the blood which has been carried into all the organs by the arteries, and brought back by the veins to the heart, cannot be returned into them (the arteries) without having first passed through the lungs, aerial, spongy viscera, forming a medium which the blood must necessarily traverse to pass from the right into the left cavities of the heart: this passage constitutes the pulmonary or smaller circulation. It does not exist in animals of cold blood. In them the heart has only one auricle and one ventricle; the pulmonary arteries are merely branches of the aorta, and carry into the lungs or the organs that supply their place a very small quantity of blood: it is on this account the habitual temperature of those animals is much below that of man; it is also from that reason there exists so little difference between arterial and venous blood: the quantity of the fluid vivified by the contact of the air in the pulmonary structure, is too small to produce any remarkable change in the whole mass.

LI. Mayow has given the most accurate idea of the respiratory organ, in comparing it to a pair of bellows, in the inside of which was an empty bladder, the neck of which was adapted to the instrument, and gave entrance to a column of air when its parietes were separated: the air, in fact, does not enter the lungs but when the thorax dilates and enlarges by the separation of its parietes. The active powers in respiration are, therefore, the muscles which move these parietes, formed by soft and hard parts, so that they unite to a solidity proportioned to the importance of the organs inclosed in the chest, a mobility necessary for the exercise of their functions.

To effect respiration, which may be defined the alternate entrance and egress of air in the lungs, the thorax must expand (the name of inspiration is given to this active dilatation of the cavity) and contract to expel the air which had entered during the first process. This second motion is called expiration; it is always shorter than the other, its causes are more mechanical, and the muscular powers have less influence.

The parietes of the thorax are formed behind by the spine or columna vertebralis, before by the sternum, and laterally by the ribs, bony and cartilaginous arches obliquely situated between the immovable spine, which becomes a point of support to their motions and the sternum, that possesses a certain degree of mobility. The spaces between are composed of thin muscles, the external and internal intercostals, the fibres of which have an opposite direction; and besides these there are several muscles passing from the external part of the chest to be attached to bones in its vicinity, as the subclavius, pectoralis major and minor, latissimus dorsi, scaleni, longissimus dorsi, sacro-lumbalis, serratus posticus minor, superior and inferior. But of all the muscles that enter the composition of the anterior, posterior, and lateral parts of the chest, there is no one so important as the diaphragm, a fleshy and tendinous separation, situated horizontally between the thorax and abdomen, attached to the cartilages of the false ribs and to the vertebræ of the loins; it is perforated by three apertures for the passage of the œsophagus, and vessels that ascend from the abdomen into the thorax, or descend from the thorax into the abdomen.

The thorax in its usual state dilates only by depressing the diaphragm. The curved fibres of this muscle, made straight by the contraction, descend towards the abdomen, depressing its viscera; the latter push forwards the anterior parietes of this cavity, which sink down when expiration succeeds; the diaphragm is then relaxed, and ascends, being pressed back by the abdominal viscera on which the large muscles react. When we have occasion for the admission of a great quantity of air into the chest, it not only enlarges in length by the descent of the diaphragm, but its capacity is likewise increased in every direction. The intercostal muscles then contract, and approximate the ribs between which they are placed; yet the intercostal spaces become larger, particularly at the anterior part; for whenever oblique lines tend to become perpendicular to a vertical line, and to form right angles with it, the intercepted spaces augment in proportion as the lines, having been more oblique, approach the horizontal direction. Besides, as the ribs present a double curvature in respect to their length, one on their front, the other on their sides; the convexity of the former is outwards: they separate from the axis of the chest, the cavity of which is enlarged transversely, while the latter curvature, agreeably to its edges, being augmented by a true rotatory motion of these bones, perceptible in their cartilaginous parts, the sternum is pushed forwards and upwards, so that the posterior extremity of the ribs becomes more distant from their connexion at the sternum. But as the ribs admit of unequal degrees of motion, the first is almost entirely fixed, and the mobility of the others increases with their length; as they descend, the sternum performs a kind of reciprocal motion, by which its inferior extremity is pushed forwards. The thorax, therefore, increases both in its right and transverse diameter, each of which has been estimated to expend two lines (a line is the tenth part of an inch): the extension of the vertical diameter dependent on the descent of the diaphragm is much more considerable.

LII. Professor Sabatier maintains, in a memoir on the motion of the ribs, and action of the intercostal muscles, that the superior ribs, during inspiration are alone elevated; that the inferior ribs descend, and are carried a little inwards, whilst those occupying the middle space are carried outwards; and in the motion which succeeds, that the first descend, the second reascend, and the third pass inwards. He also says that the disposition of the cartilaginous surfaces, by which the ribs are articulated with the transverse processes of the spine, are so disposed as to favour these different motions, since the superior are directed upwards, the middle forwards, and the inferior downwards. But if we attend particularly to the surfaces by which the transverse processes of the dorsal vertebræ articulate with the tuberosities of the ribs, they are mostly turned directly forwards; some of the inferior are also directed a little upwards. If we examine the motion of some of the bones of the chest during inspiration, on a very lean person, as a pulmonic patient, whose skin seems only to cover the bones, we see that all the ribs are elevated and carried a little outwards. There is some difficulty in perceiving how the intercostal muscles, which professor Sabatier considers to be expiratory powers, should elevate the upper and depress the lower ribs: the diaphragm, the circumference of which is attached to the latter, would produce this effect in contracting; but as the intercostal muscles have the fixed point of their action universally in the upper ribs, they counterbalance and neutralize this effort, and all the ribs are at once raised. If it were otherwise, they would be carried downwards when the intercostal muscles contract, since the inferior ribs attached to the diaphragm would become the fixed point on which the others should act.

As the external and internal intercostal muscles have fibres in opposite directions, those of the former being oblique from above downwards, and from behind forwards, and crossing the others obliquely in a contrary course, some physiologists have thought that they were on the principle of antagonist muscles, and that the internal intercostals serve to approximate the ribs, which were separated by the external; that one kind was, therefore, *expiratores*, the other *inspiratores*, or muscles which contract during inspiration.

It is well known with what tenacity the physiologist Hamberger, in other respects a well-informed man, defended this erroneous doctrine in his controversy with Haller; but it is at present well established, that all the intercostals concur to dilate the thorax, and that they ought to be considered among the inspiratory powers, because the unequal range of motion in the ribs prevents the internal intercostals, the attachment of which is lower, and nearer the articulation of these bones with the vertebræ, from carrying down the superior ribs. I shall only cite one of the most decisive experiments, instituted by Haller, to refute the opinion of his adversary, which consisted in denudating the thorax of a living animal of all the muscles covering it, and of raising the external intercostal muscles in several places: the internal are then seen to contract during inspiration, exactly at the same time with the remaining part of the external intercostals; these are therefore concurrent, and not antagonist muscles. We are also informed by the same experiment, of the increase of the intercostal spaces; the finger placed between two ribs is not so much confined in inspiration, when these bones are elevated and push forwards the sternum.

LIII. When any cause whatever renders inspiration difficult, prevents the diaphragm from descending towards the abdomen, or in any other manner impedes the motion of inspiration, the intercostal muscles not only evidently act to induce a dilatation of the thorax; but also several other auxiliary muscles, as the scaleni, subscapulares, pectorales, serrati majores, latissimi dorsi, in contracting raise the ribs, and increase the diameter of the thorax in several directions: the fixed point of these muscles should then be their movable part, because the cervical spine, the clavicle, scapula, and humerus, are fixed by other powers which it would be needless to enumerate. Any person who observes the access of a convulsive asthma, or the paroxysm of a severe cough, may easily appreciate the importance and action of these auxiliary muscles.

Inspiration is a state truly active, an effort of the contractile organs, which must cease when they fall into a state of relaxation. Expiration, which succeeds, is a passive motion, in which few muscles cooperate, and chiefly depends on the reaction of the elastic parts constituting the structure of the parietes of the chest. It has been seen that the cartilages of the ribs experience a degree of rotation carrying their upper edge backwards and downwards: when the cause that is productive of this action ceases to act, the parts return upon themselves, and carry back the sternum on the spine, towards which the ribs descend by their own gravity. The diaphragm is pushed nearer the thorax by the abdominal viscera, on which the large muscles of the abdomen react.

In every effort of expiration, as coughing and vomiting, these muscles react not only in consequence of their own elasticity; they still contract and approximate the spine, propelling the viscera towards the thorax. The musculus triangularis of the sternum, the sub-costales, and the serratus minor inferior, may be ranked among the *expiratores;* but they are seldom employed, and form too slender and weak powers to contribute much to the contraction of this cavity.

LIV. When the chest enlarges, the lungs dilate, following the parietes which expand. These soft, spongy viscera, of a less specific gravity than common water, covered by the pleura, which is reflected over them, are always contiguous to a portion of this membrane, which lines the internal surface of the thorax; there is no air between their surface, which is constantly moistened by a fluid that exhales from this membrane, as may be demonstrated by opening the chest of an animal under water, when not a bubble of air is disengaged from it. In proportion as the lungs dilate, their vessels expand, and the blood passes through them with more facility; the air filling the innumerable cells of their aerial texture, rarefies according to the extension of space in which it is contained, and in consequence of internal heat it does not well resist the pressure of the atmosphere which enters in columns by the nostrils and mouth, descending into the lungs through the larynx, that is always open except during the act of deglutition.

LV. The structure of the lungs, into which the air is thus drawn each time the capacity of the chest is enlarged, is not only formed by air vessels that are larger or smaller; by ramifications of the two principal ducts in which the trachea terminates; and by the lobular texture into which the air is deposited; there is also a great quantity of sanguiferous vessels, lymphatics, and nerves: cellular structure unites these parts, and forms them into two masses of nearly equal dimensions, covered by the pleura, and suspended in the chest by the bronchiæ and trachea. The lungs are every where contiguous to the parietes of the cavity, except at their root, at which the nerves and every kind of vessels penetrate.

> It is well known that the right lobe is a little larger than the left; the former is divided into three principal lobuli, the latter into two only.

The pulmonary artery arises from the base of the right ventricle, and divides into two, one for each lung; having entered into the substance of these viscera, they subdivide into so many branches as there be principal lobuli; from these proceed others; and ultimately the ramifications become capillary vessels, which terminate by being continued into the radicles, or origin of the pulmonary veins.

These vessels, arising from the extremities of the artery, reunite and form trunks, which successively increase in magnitude, pass out of the lungs, and being four in number, open into the left auricle. Besides these large vessels, by means of which the right form a communication with the left cavities of the heart, the lungs receive from the aorta two or three arterial branches, known by the name of bronchial arteries; these are spread in their texture, following the distribution of other vessels, and terminate in the bronchial veins, which open into the vena cava superior, near its communication with the right auricle.

A prodigious number of absorbent vessels arise from the surface and internal substance of the lungs, and may be divided into superficial and deep-seated: the latter accompany the bronchiæ, and pass through glands placed at the division of the air-vessels, but more particularly collected towards the root of the lungs, and in the angle made by the bifurcation of the trachea. These bronchial glands, which belong to the lymphatic system, do not differ from glands of that kind, and are only remarkable by their number, magnitude, and blackness, which is their usual colour. The lymphatic vessels of the lungs, after having ramified in these glands, open into the superior part of the thoracic duct, at the distance of some inches from its termination in the subclavian vein. The lungs, though possessing but a moderate degree of sensibility, have a considerable number of nerves from the great sympathetic, and particularly from the eighth pair.

It has long been believed, since the time of Willis, that the aerial texture of the lungs was vesicular; that each ramification of the bronchiæ terminated in their substance, forming a small vesicle: at present the generality of anatomists adopt the sentiments of Helvetius. According to him, each bronchial tube terminates in a small lobe, a kind of aerial sponge formed by a certain number of little cells that communicate together; the union of these lobules by means of cellular texture forms larger lobes, and they ultimately, by their assemblage, constitute the mass of the lungs.

The structure uniting together the lobules and lobes, is very different from that terminating the ramifications of the bronchiæ; the air never penetrates into it, except in cases of a rupture of their peculiar structure. Under these circumstances, which sometimes take place on account of the extreme tenuity of the laminæ which constitute the parietes of the cells of the texture of the latter, the lung loses its usual form, and becomes emphysematous. Haller considers the coats of these aerial cells to be the millionth part of an inch in thickness, and as the ultimate ramifications of pulmonary vessels are spread on their parietes, the blood is almost in immediate contact with the air. There is no doubt but that the oxygen of the atmosphere, can then act on the liquid, since it effects a change, and alters it to a bright red when a hog's bladder filled with blood is kept some time suspended under a bell filled with this gas.

LVI. Each time the thorax dilates in an adult man, from thirty to forty cubic inches of atmospheric air enter into the lungs; and when in a state of purity, composed of seventy-three parts of azot, twenty-seven parts of oxygen, and $\frac{1}{100}$ or $\frac{2}{100}$ of carbonic acid.

Some physiologists believe that the volume of air inhaled is much less. Professor Gregory of Edinburgh teaches in his public lectures, that hardly two inches enter at each inspiration; yet this calculation can be proved incorrect, either by causing a strong inspiration to be made, as practised by Mayow, from a certain quantity of air contained in a bladder, or in expelling the air received by a strong inhalation into a bell of the pneumato-chemical apparatus. We can likewise distend the lungs of a dead subject, to the trachea of which a stop-cock is adapted, and then, by means of a curved tube, pass the air under the same apparatus.

Various means have been employed to estimate the capacity of the lungs. Boerhaave caused a man to be put into a large tub of water above his shoulders, and desired him to make a strong inspiration; he measured the elevation of the liquid after a dilatation of the chest. Keil distended the lungs with water. It has been proposed to inject the bronchiæ and lobular texture, in which they terminate, with the fusible metal, which is an alloy of eight parts of pewter, five of lead, and three of bismuth, to which may be added one part of mercury.

After the atmospheric air has remained some moments in the pulmonary structure, it is expelled by the effort of expiration; but its quantity is diminished: it is reduced to thirty-eight inches. Its composition is not the same: there are found, certainly, $\frac{73}{100}$ of azot, but the oxygen, its vital and respirable part, has suffered great diminution; its proportion is only $\frac{14}{100}$: carbonic acid constitutes the remaining $\frac{13}{100}$, and sometimes one or two parts of hydrogen gas are found. It is likewise altered by the mixture of an aqueous vapour, which condenses in cold weather in passing out through the nostrils and mouth: it is known by the name of the humour of pulmonary exhalation. These changes, compared with those which the blood has suffered in its passage through the lungs, manifestly indicate a reciprocal action of this liquid and the oxygen of the atmosphere. The dark venous blood, slow of coagulation, and separating much serum, loaded with hydrogen and carbon, possessing only thirty degrees of heat, gives off to the oxygen of the atmosphere its hydrogen and carbon, to constitute the carbonic acid and pulmonary vapour; and as oxygen cannot enter these new combinations without disengaging a portion of caloric, which rarifies it into gas, the blood seizes this heat, now liberated with so much greater facility as it proportionally loses its hydrogen and carbon, and agreeably to the ingenious experiments of Crawford, its capacity for caloric augments in the relation of 10 : 11 : 5.

The blood, in relinquishing its carbon, which, combined with oxygen, forms the carbonic acid given off in expiration, changes its dark and almost violet colour to a bright vermilion-red; its consistency is increased by the dissipation of its hydrogen and aqueous parts; besides, as it absorbs a certain quantity of oxygen, it becomes frothy and lighter, its concrescibility and plasticity increase, and on coagulation less serum is separated.

The blood, in its passage through the lungs, is deprived of hydrogen and carbon, and, in becoming arterial, is loaded with oxygen and caloric. In proportion to its distance from the heart, it is deprived of its oxygen and caloric, which are formed into oxyds of hydrogen and carbon; these, by a fresh addition of oxygen, when under the influence of atmospheric air in the lungs, form water and carbonic acid.

Arterial blood becomes venous by parting with its oxygen when any cause suspends or retards its course, as proved by the following experiment of J. Hunter. He tied the carotid of a dog in two places, at about four inches distance; the blood which came out of that portion of the artery between the ligatures, when opened several hours afterwards, was coagulated and dark like that of the veins. The blood which distends aneurismal sacs, frequently liquid when the rupture of the internal coats of the artery is recent, by remaining there, passes into the venous state; yet the alterations the blood suffers in passing through the system of arteries are not very remarkable, on account of the rapidity with which it passes through this order of vessels; and there is less difference between the blood of an artery in the vicinity of the heart and that of another very distant artery, than there exists between the same fluid in the extremities of the veins, and in their large trunks near the right auricle. The blood flowing in small veins very much resembles that of the arteries; and often in a copious bleeding the colour of the blood, at first very dark, becomes gradually paler, so that towards the end of the operation, the blood which flows exhibits the qualities of that in the arteries, a phenomenon well known to the English author just quoted, and which is occasioned by rendering a more easy and direct passage of the blood from the arteries into the veins, by emptying the venous system. This observation clearly refutes Bellini's assertion: according to his doctrine, the blood that flows from a wounded vein forms a double stream, which passes out of the orifice. This opinion is embraced by most respectable physiologists, as Haller and Spallanzani, who support it with experiments made on the vessels of animals of cold blood, or veins destitute of valves. In a bleeding at the flexure of the arm, the blood cannot come from that part of the vein above the puncture; the valves oppose an insurmountable obstacle to its retrogradation: thus we perfectly distinguish the red blood coming from the inferior part, from the small quantity of black blood that flows from the superior part, poured into the vein by those veins which are situated in the space between the incision and the nearest valve.

In traversing the parts in which the arteries are distributed, the blood, revivified in its passage through the lungs, according to the expression of Fourcroy, *reconstitué pour une nouvelle vie*, then loses its oxygen and caloric: its affinity to the latter diminishes in proportion as the oxygen, by combining with the hydrogen and carbon, causes it to return into the state of venous blood.

This theory of the disoxygenation of blood, in passing through sanguiferous vessels, acquires a new degree of probability from the recent discoveries on the nature of the diamond. This body is the only pure carbon, and the substance to which chemists gave this name is an oxyd of carbon, deriving its black colour from the oxygen with which it is combined. Before these experiments it was difficult to determine the particular state of carbon that forms such a considerable part of venous blood.

We have not yet precisely determined the respective quantities of oxygen absorbed by venous blood, and of the same oxygen employed to disengage the hydrogen and carbon in the lungs, to form the water and carbonic acid.

Is the carbon in venous blood only combined with oxygen, or united with hydrogen, forming an hydro-carbon? It seems to me more probable that the oxygen absorbed, in uniting with the hydrogen in every part of the body, produces the water that dilutes the venous blood, renders it more fluid, and abounding in serum than arterial blood; whilst in uniting with carbon it forms an oxyd that gives this blood a dark colour, constituting one of its principal characteristics. The water, when in the lungs, which are true secretory organs, exhales, dissolved by the air, and forms pulmonary transpiration or exhalation; the oxyd of carbon, more completely burnt by a superaddition of oxygen, constitutes carbonic acid, which gives the air passed by expiration the property of precipitating lime-water.

By means of the absorption of oxygen by venous blood, we can explain how the phenomena of respiration continue in every part of the body, and give rise to heat, uniformly spread throughout all our organs. In proportion as the blood loses its caloric, for which its affinity or capacity diminishes as it becomes venous, the parts which give off their hydrogen and carbon seize it. If the lungs were the only organs in which the matter of heat could be disengaged, the temperature of these viscera should be much higher than that of other parts, and experience proves that it is not sensibly augmented.

This theory of respiration, for which we are entirely indebted to modern chemists, is not contradicted by any phenomenon. The more capacious the lungs, so much the more frequent is respiration; animals have, in consequence, more heat and vivacity. Birds, whose pulmonary organs are continued into the abdomen by several membranous sacs, and whose hollow bones communicate with the lungs, consume a great quantity of oxygen, either on account of the extent of their pneumatic receptacle, or because their respiration is frequent, and often sudden: thus the habitual temperature of their body is ten degrees above man and the mammiferi, or those having teats. In reptiles, on the contrary, the vesicular lung of which receives only a small quantity of blood, and offers but a small surface, respiration takes place at more distant intervals: consequently they have a temperature never above seven or eight degrees.

Animal Heat.

LVII. Although the warmth or temperature of the body be generally proportioned to the extent of respiration, and to the quantity of blood passing under the influence of atmospheric air in a given time, it can be greater or less according to the degree of the vital energy of the lung. This organ should not be considered as a chemical recipient; it acts on the air, as the ancients observed, and combines it with the blood by a peculiar power; if it were otherwise, nothing would prevent the revival of a dead person by propelling oxygen into the lungs. The ancients had expressed this action of the lungs on the air inhaled, by calling it the aliment of life, *pabulum vitæ* of Hippocrates, the digestion of which, in their opinion, was effected in the lungs in the same manner as that of food in the stomach, which was, in fact, considered less essential to life, as a privation of it could be sustained for a certain time, whilst life is endangered when the aerial aliment might cease to be supplied to the lungs during the short space of a few minutes. If the body become cold in certain nervous and convulsive affections, this coldness, perhaps, depends as much on an atony of the lungs, the sensibility of which goes to be concentrated on the affected organs, as on the spasmodic affection of the parietes of the thorax, which only dilate with difficulty, and do not easily permit air to pass into them.

We may adduce in proof of the vitality of the lungs, and of the part they take in the changes the blood undergoes in traversing them, the experiment which informs us that an animal put under a bell filled with oxygen, and respiring the gas in a state of purity, does not consume more of it than if it had entered into the lungs combined with non-respirable gases. If we put a guinea-pig under a bell of known dimensions filled with vital air, he will live four times longer than if it contained common air of the atmosphere. Considerable changes are not at first perceived in the act of respiration; but if an animal remain long plunged in oxygen, inspiration and expiration become more frequent, the circulation more rapid, and all the vital actions are performed with greater energy. The lungs separate the two atmospheric gases by a peculiar power; for the oxygen does not leave the azot but with difficulty, to be carried into the blood, since this liquid, exposed to the open air, becomes black, though spread in thin laminæ.

It is observed, that an animal changes the air filling the vessel under which it is placed with greater celerity in proportion as it is younger, more robust, and its lungs of greater extent. Thus birds, the lungs of which are very capacious, effect a change on a greater quantity of air at once, and more speedily consume its oxygen; a frog, on the contrary, can remain a long time in the same air without depriving it of its oxygen. The vesicular lungs of this reptile, as of all other oviparous animals, are much more irritable than those of animals of warm blood; they seem to contract conformably to the volition of the animal. The frog, when deprived of its diaphragm, draws the air into the lungs, swallowing it by a true deglutition, as proved by professor Rafn, of Copenhagen, who killed frogs at pleasure only by keeping their maxillæ separated for a certain time. This animal ejects the air by contracting its lungs, by the same mechanism as in man the bladder is evacuated of urine.

Birds, of which the diaphragm is also membranous, and perforated by a number of apertures that transmit the air into the pulmonary structure, have the other parietes of the chest more movable than in man and quadrupeds; their pectoral muscles are more developed, their ribs are connected by an articulation at the middle parts of these curvations, which are entirely bony in this class of animals; and these two portions move on each other, forming at the place of their union angles more or less acute, in proportion as the sternum approaches to, or recedes from the spine.

A numerous class of animals of red and cold blood (fish) are destitute of lungs; the gills, which supply their place, are small, penniform, flat bodies, generally four on each side, on the posterior and lateral part of the head, covered by a movable top, called by naturalists *operculum*. The water swallowed by this animal passes through the parietes of the pharynx, perforated by large apertures, washes the gills and pulmonary vessels there situated, and then escapes by the auricular openings when the mouth is shut and the *opercula* raised. We are still ignorant whether the water, decomposed, gives its oxygen to blood flowing in the gills, or whether it be only the small quantity of air dissolved in the water that is capable of vivifying the pulmonary blood. This latter opinion will appear very probable, by considering that we can suffocate a fish by completely closing the top of a vessel of water in which it is contained: the same result would be obtained by putting the glass under the receiver of an air-pump, and exhausting the air as much as possible.

The warmth of the body, independent of that of the atmosphere, is not only produced by combinations in the lungs and circulation, it is also developed in several organs where fluid or gaseous substances become solid by parting with a portion of their caloric: thus digestion, particularly in certain animals, is an abundant source of heat: thus the skin, continually affected by the contact of the atmosphere, decomposes it, and receives part of its caloric. In fact, heat arises and is disengaged in all parts, the particles of which are agitated by a double motion, by means of which they are continually composed and decomposed. It is doubtless to this great activity of the assimilating powers in infancy, that a more elevated temperature is habitual.

For a more ample account of animal heat, see the introduction to this work.

LVIII. The rapidity with which the blood passes through the lungs, is equal to the celerity with which it flows through other organs; for, if the parietes of the right ventricle and pulmonary arteries have less power and thickness than those of the left ventricle and the aorta, the lung, on account of its soft, dilatable, spongy structure, is the most permeable of all our organs, and that which liquids penetrate into and pass through with the greatest facility.

The right ventricle sends into the lungs a quantity of blood equal to that which each contraction of the left ventricle propels into the aorta (about two ounces). It is not necessary to admit with Mr. Kruger, that the same volume of blood passes at the same time into the lungs as into the rest of the body, in which case the circulation must have been much more tardy, since their extent is by far less than that of the whole body; nor can we conclude with Boerhaave, that this circulation is much quicker, because an equal quantity of blood should be furnished by the extremities of the pulmonary artery, and by the other arterial extremities of the body.

The extension of the pulmonary structure, and the contraction of vessels, doubtless facilitate the passage of the blood; but if the admission of air had no other utility, respiration would not be indispensably necessary; yet the blood passes from the right into the left cavities of the heart, notwithstanding the pressure of the lungs, and the folds of their vessels. The changes effected by the contact of atmospheric air, renovate and render it capable of reanimating and keeping up the action of all the organs, for which arterial blood is a necessary stimulus. If we make an animal respire air deprived of oxygen, the blood suffers no alteration in its pulmonary circulation; the left cavities of the heart are no longer strongly irritated by this fluid, which retains all its venous qualities; their action languishes, and with it that of all the organs, and soon becomes extinct. It is reanimated if we propel pure air by means of a tube adapted to the trachea; all parts seem to revive as from a profound sleep, into which they relapse if returned into the same air, and are again deprived of the vivifying salutary gas.

The chyle, copiously mixed with venal blood, in passing through the heart and sanguiferous vessels, suffers a stronger commotion; its particles come into mutual contact, are attenuated, and better mixed: a great quantity of this fluid, in passing through the lungs, is deposited by a kind of internal perspiration on the parenchymatous substance of these viscera. When oxydated by the contact of the air, and reabsorbed by a number of inhalent vessels, it is carried into the bronchial glands, which are blackened by the carbon and fuligo there deposited. When purified by this elaboration, it again enters the thoracic duct, which pours it into the subclavian vein, whence it soon returns to the lungs, to be a second time subject to the influence of the atmosphere; so that it performs a true lymphatic circulation through these organs, to give the chyle a higher degree of animalization.

Pulmonary Transpiration, or Exhalation.

LIX. It should be remembered that one of the principal differences that exist between the blood of arteries and that of veins, is the great quantity of serum contained in the latter; it is in the lungs that this aqueous part separates from it, and becomes diminished, either because the albumen and gelatin existing in it are rendered concrescible by the oxygen, or the serum formed by the fixation of oxygen throughout the whole extent of the circulatory system may exhale from the arteries, and thus furnish the matter of pulmonary transpiration. It is hardly possible to admit that oxygen combines with the hydrogen of venous blood, and that water is consequently formed by both, as happens during a storm in the higher regions of the atmosphere. If a similar combination can take place in the lungs without producing a deflagration, and different phenomena that accompany the production of aqueous meteors, it is probable that it only gives rise to a small part of transpiration; and that this humour, analogous to the serum of the blood, exhales, already formed from the arterial capillary vessels ramified in the bronchia of the lobular structure of the lungs. It is believed that the quantity of pulmonary transpiration is equal to that of the skin (four pounds in twenty-four hours). These two secretions reciprocally accommodate each other; so that when a great quantity of fluid has passed off by pulmonary exhalation, cutaneous transpiration is in smaller quantity, and *vice versa*.

The surface, from which the pulmonary transpiration exhales, has an equal, if not greater extent than that of the cutaneous organ: this surface is both exhalant and absorbent; numerous nerves are there distributed and almost uncovered in the texture of extremely fine membranes. Are the *miasmata;* with which the air is sometimes loaded, absorbed by the lymphatics, which it is well known can seize gaseous substances, or do they only produce an impression on the nervous and sensible membranes of the bronchiæ and of the lobular structure; whence arise the diseases of which they are the germ?

A part of the caloric disengaged by the combinations of the oxygen in the lungs, is employed to dissolve and convert into gas the pulmonary transpiration, which is by so much the more abundant as respiration is complete.

> It is necessary to distinguish pulmonary transpiration from the mucus secreted on the interior surface of the bronchiæ and trachea, which is thrown off by strong expirations, and forms the matter of expectoration.

Asphyxiæ.

LX. Although the term asphyxia merely signify the absence of the pulse, yet the name is applied to every apparent loss of vitality, produced by an external cause that suspends respiration, as drowning, strangling, disoxygenation of the air we breathe, &c. The only existing difference between real death and asphyxia, is, that, in the latter state, the principle of life can be reanimated, while in the former it is completely extinct.

Asphyxia by *drowning* or *submersion*, always depends on the lungs being deprived of air; the blood that passes through them does not therefore become impressed with qualities essential to the preservation of life. Water does not enter these viscera when a man drowns himself; the spasmodic contraction of the glottis prevents this liquid from penetrating into the aerial tubes; yet there is a small quantity found in the bronchiæ of drowned persons always frothy, because the air is mixed with it in the efforts preceding asphyxia. If the body remain long under water, the spasmodic state of the glottis ceases, the water rushes into the trachea, and fills the pulmonary texture. An anatomical investigation of the body of a drowned person presents the lungs collapsed and in a state of expiration; the right cavities of the heart, the venous trunks opening into it, and the veins in general are distended with blood, while the left cavities and the arteries are almost totally empty.

> Hence arises the black and livid colour of the skin and conjunctive membrane. This latter membrane is frequently filled with a blackish blood, the veins of the brain are considerably dilated, and this viscus is truly surcharged with venous blood.

Life is extinct in this kind of asphyxia, because the heart sends to the other organs, and particularly the brain, a blood deprived of principles necessary for their action; and perhaps also, because the venous blood, accumulated in every structure, affects them with its blunting and mortiferous qualities; therefore a mechanical inflation of the lungs with pure air is the most powerful method that can be adopted to recover them: a pair of bellows adapted to a canula previously introduced into the nostril is used for that purpose. If this apparatus be not at hand, the mouth should be applied to that of the drowned person, or, by means of a tube, to the nostrils; but as the air thus expired has already served the purposes of respiration, it is neither so abundant in oxygen, nor so well adapted to revive the action of the heart. There are likewise many other, but less efficacious remedies, as frictions, bronchotomy, clysters, fumigations, suppositories, irritating errhines, and particularly ammoniac; stimuli carried into the mouth and stomach, burning, bleeding, baths, and electricity.

The redness and livid colour of the face of persons killed by hanging, had induced a belief that they die of apoplexy; but it seems that in asphyxia by *strangulation*, as well as by submersion, it is to the interception of air that death is to be attributed. Gregory, to prove this, made the following experiment: after having opened the trachea of a dog, he passed a slip-knot round the neck, above the wound. The animal, though hanged, continued to live and respire, the air was alternately admitted and expelled through the small opening: he died when the constriction was made below it. A surgeon of the imperial armies, whose veracity cannot be questioned, assured me that he had saved the life of a soldier by performing the operation of laryngotomy some hours before he was executed.

Nevertheless, the death of hanged persons may take place by the luxation of the cervical vertebræ, and injury of the spinal marrow, as a necessary consequence. It is known that Louis discovered, that of the two executioners of Paris and Lyons, one despatched the criminals condemned to be hanged by luxating the head on the neck, whilst those who perished by the hands of the other were completely strangled.

Of the various non-respirable gases, some seem to produce asphyxia only by depriving the lungs of vital air, necessary to the support of life, while others evidently affect the organs and blood in them with a poisonous and deleterious principle.

Among the first we may reckon carbonic acid; in the kind of asphyxia occasioned by this gas, which is of all the most frequent, and to which those celebrated men of antiquity, Cicero, Juvenal, Valerius Maximus, Florus, and

Plutarch, were victims, the blood preserves its fluidity, the limbs their flexibility, and the body its natural heat, or even an increased degree of heat, for some hours after death. We easily see how difficult of explanation this phenomenon becomes, if the chemical theory of the production of animal heat be rigorously admitted. The lungs in this asphyxia, as in all others, remain entire; the right cavities of the heart and venous system are filled with black but fluid blood. In those, on the contrary, produced by sulphurated or phosphorated hydrogen, &c. or certain vapours little known, from the exhalations of privies or burial-places, where numerous bodies go into a state of putridity, the lungs are often covered with black and gangrenous spots, and death seems to be the effect of a poison, so much the more active as its parts being extremely divided and reduced to a gaseous state, are more penetrating, and affect the nervous, and sensible surface of the pulmonary organ throughout its whole extent.

It is extremely uncommon for intoxication to produce asphyxia; it generally induces a state of profound sleep, or insensibility, easily distinguishable from the affection here treated of (asphyxia), by the beatings of the pulse, often obscure, and by the motions of respiration, which are neither frequent nor strongly marked. Thus Pinel, in his *Nosographie Philosophique*, has placed asphyxia and intoxication as two separate genera in the class neuroses; yet we can conceive that the affection of the irritability of muscles by spirituous drinks may be so strong, that the diaphragm and heart shall cease to contract, whence a true asphyxia would necessarily succeed.

The aperture of the glottis, through which the atmospheric air must pass to get into the lungs, is so small, that it may be easily closed when the body to be swallowed stops at the entrance of the larynx, as the epiglottis is raised at the time of deglutition; a grape-seed can produce this effect: it is thus that Anacreon, the admirable painter of pleasure and the Graces, is said to have died. Gilbert the poet terminated his existence in a similar manner, after a long and painful suffering; he was a man of great appetite, and in the midst of a festival went into a neighbouring room, but did not return, to the great surprise of his convivial companions. He was found stretched on a couch without any marks of life. The assistance administered by his kind but uninformed friends was useless; on opening the body a small piece of mutton was found, that had stopped at the entrance of the larynx, and completely prevented the passage of air into this organ.

See the history of delivery and of the fœtus, on the asphyxia of new-born children.

On certain Phenomena of Respiration, as Sighs, Crying and Sobbing, Gaping, Sneezing, Hickup, Laughing, &c. &c.

LXI. When the imagination is particularly occupied by an object, the vital functions fall into a state of languor, the principle of life seems to abandon all the organs, to be concentrated in those which most participate in the mental affection. When a lover, plunged in soft reveries, at intervals fetches deep sighs, the physiologist only remarks, in this expression of desire, a strong and protracted inspiration, by which the lungs are greatly dilated, and offer the blood, which had been accumulated in the right cavities of the heart, a free passage into the left cavities of this organ. This deep inspiration, to which succeeds a similar expiration, and which is often accompanied by moans, becomes necessary, because the motions of respiration being progressively retarded, are no longer sufficient for the dilatation of the pulmonary structure.

Crying and sobbing differ from sighing, by the long expiration being interrupted, that is, divided into several distinct periods.

Gaping is effected by an analagous mechanism; there is no smyptom more evident of weariness; an unpleasant affection, which, in the language of Brown, may be considered as an asthenic or debilitating power. The inspiratory muscles are weakened, and dilate the thorax with difficulty; the lungs contracted, and not easily permeable to the blood, which stagnates in the right cavities of the heart, and produces an uneasy sensation that is removed by a deep and strong inspiration: the entrance of a great quantity of air is facilitated by opening the mouth wide, and by separating the maxillæ. We gape at the approach of sleep, because the inspiratory powers become gradually weakened, and require to be stimulated at intervals; we gape also in awaking, to raise the muscles of the thorax to a degree necessary to carry on respiration, which is always slower and less frequent during sleep than when awake.

During the time which gaping continues, the perception of sounds is less distinct; the air which rushes into the mouth is carried into the Eustachian tube, and produces a counter-affection on the membrane of the tympanum. The remembrance of the convenience before procured by a long inspiration, induces us to repeat it involuntarily whenever another person performs that action in our presence.

Sneezing consists in a strong and violent expiration, in which the air passing out with rapidity strikes against the winding parietes of the nasal fossæ, and occasions a remarkable noise. The irritation of the pituitary membrane sympathetically causes this effort, which is a truly convulsive motion of the muscles of the chest, and chiefly of the diaphragm.

Coughing greatly resembles sneezing, and only differs from it in the expirations being shorter and more frequent. The air, as in sneezing, clears the pituitary surface, and removes the mucus that may be attached; in coughing it carries off that which is lodged in the trachea and bronchiæ, and constitutes expectoration.

Laughing is merely a succession of very short and rapid inspirations and expirations. In the hickup, the air drawn with rapidity enters the larynx with difficulty, on account of the spasmodic affection of the glottis; and being propelled with some violence, it strikes forcibly against the sides of this aperture, whence arises the peculiar sound that accompanies it.

We shall explain hereafter the mechanism of suction, anhelation, or panting, and of the efforts by which the muscles of the thorax fix the parietes of this cavity, so that it may serve as a point of support for the action of other muscles of the trunk and extremities.

Respiration serves also for the formation of the voice; but we shall treat of this sound, and the different modifications of which it is susceptible, in a separate chapter.

Cutaneous Transpiration.

LXII. An abundant vapour continually exhales from the whole surface of the body, and has the name of insensible transpiration, or perspiration, when it is invisible to the naked eye, and passes off in a state of gas; but is called sweat, when, becoming more copious, it flows in form of a liquid. Sweat, therefore, only differs from insensible transpiration in the state under which it appears, and is produced when the air can no longer carry it off in vapour, either from the skin secreting more than usual, or the atmosphere, possessing more humidity, does not so well dissolve it. Insensible perspiration continually escapes from the innumerable pores of small arteries that are distributed in the teguments; it exsudes into the interstices of the laminæ of the epidermis or cuticle: the air surrounding our bodies receives and carries it away. The greatest resemblance exists between cutaneous and pulmonary transpiration; both are simple arterial exhalations, and the mucous membrane that lines the internal surface of the aerial passage, is a continuation of the cutis expanded over these organs as on the intestinal canal. The surface from which cutaneous perspiration exhales is smaller than that from which pulmonary transpiration arises, since it is only estimated at fifteen square feet in a man of moderate stature: in fact,, these two secretions mutually counterbalance the augmentation of one, and constantly occasion a sensible diminution in the quantity of the other. Finally, the mucous membrane of the intestinal canal exhales, besides the mucus secreted, a liquid which is considerably increased when the perspiration of the skin is diminished, as proved by serous diarrhœas, so frequently induced by suppressed perspiration; yet it must be confessed, notwithstanding these analogies of structure and use between the skin and mucous membranes, that there exists, perhaps, a closer connexion between its action and that of the secretory organs of the urine: it has been observed in all ages, that when the latter liquid is less copious, a greater quantity of fluids pass off by the skin, and *vice versa*.

If the naked body, exposed in summer to the rays of the sun, be examined by means of a microscope, it will appear enveloped in a cloud of vapour, which is dissipated in spreading from its surface; and if the body be before a wall lately whitened, a shadow proceeding from this exhalation will be easily perceived. We may likewise rest assured of the existence of transpiration by the following experiment: apply the end of the finger within the eighth of an inch of a glass, or any other polished body, its surface is soon tarnished by a vapour condensed into very fine drops, which are soon dissipated when the finger has been removed. In this manner it is discovered that transpiration is more or less abundant in different parts of the body, since the back of the hand presented in the same posture will not cover the glass with any vapour.

No function of the animal economy has been the subject of more rigorous labours, nor more engaged the zeal and attention of physicians, than the secretion we are now treating of. From Sanctorius, who at the commencement of the seventeenth century published in his immortal work (Medica Statica), the fruit of thirty years' experience, and with a patience imitated by few, down to Lavoisier, who with Seguin again examined insensible transpiration, assisted by the light of modern improved chemistry; we find Dodart, who in 1668 communicated to the Academy of Sciences, then lately established, the result of his observations made at Paris, under a climate different from Venice, the country of Sanctorius. Keil, Robinson, and Rye, repeated the same experiments in England and Ireland; Linnings, who instituted the same in South Carolina, and many other learned men equally estimable, as Gorter, Hartman, Arbuthnot, Takenius, Winslow, Haller, &c. have all had for their object, to determine more exactly than Sanctorius the variations of transpiration, according to the climate, season of the year, age, sex, state of health or disease, hour of the day, and quantity of other secretions.

Agreeably to the doctrine of Sanctorius, out of eight pounds of solid and liquid aliments taken in twenty-four hours, five are dissipated by transpiration, and only three by fæces and urine. Haller says this calculation is exaggerated; yet Dodart carried it still farther, and affirmed that transpiration, compared with solid excrements, was in the proportion of seven to one.

In France, and under temperate zones, the quantity of insensible transpiration differs very little from that of the urine; it may be estimated from two to four pounds in twenty-four hours. We perspire more in summer than in winter, but pass more urine in the latter season. Transpiration, like all other secretions, is less during sleep than when awake, in advanced age than in infancy, in weak than in strong individuals, and less also in damp weather than under opposite circumstances.

It may be said that perspiration is in a compound ratio of the force with which the heart propels the blood into the capillary arteries, of the vital energy of the cutaneous organ, and of the greater or less solvent faculty of the atmosphere. The stronger and more robust perspire more than others: certain parts of the skin have an increased proportion of exhalation, as seen in the palm of the hands, sole of the foot, cavities of the axillæ, &c. When the air is hot, dry, and frequently renewed, a greater quantity of fluid is passed by the skin, and the necessity of its being restored by solid or liquid aliment is then more pressing. Passing from the sun-beams into the shade in summer, is sufficient to occasion a copious perspiration, which is never more easily effected than by exercise in hot weather, when, at the approach of a storm, the atmosphere, loaded with vapours, and heated by the rays of the sun, which dart forth at intervals surrounded with clouds, cannot dissolve the matter of insensible transpiration.

Sweat may supply the place of insensible perspiration without an increased secretion of the skin: for this effect to be produced, the air should be moist and not often renewed; yet it must be confessed that sweat is most usually the consequence of an augmentation of insensible perspiration, and the warmth of a bed which promotes it, acts by exciting the powers of the circulatory organs and the energy of the cutaneous system. Sweating debilitates the body, an effect seldom produced by insensible transpiration; an excessive sweat speedily reduces the patient; it is on this account that in hectic fever, the sweating sickness, and other equally formidable diseases, it is the evident cause of a consumption mostly mortal.

It must be observed that we do not admit, to its full extent, the theory offered by M. Fourcroy in his *Systême des Connoissances chymiques*, on the nature of connexion existing between the perspiration and urine.

The matter of insensible transpiration and of sweat is for the most part aqueous: it has great analogy to the urine by holding in solution several salts, the volatilized remains of animal substance; sometimes even acids, as in the cases observed by Berthollet, where he discovered phosphoric acid in children troubled with worms, pregnant women, nurses, in whom the body exhales an odour manifestly acid. Finally, it may contain ammoniac: the smell, in certain circumstances, indicates the presence of this alkali, both in transpiration and sweat.

The air by which our body is usually surrounded, is not only useful to dissolve the aqueous vapour arising from it; some physiologists have conjectured with great probability, that the oxygen of the atmosphere can be combined with the carbon of the blood, carried to the common integuments by the very numerous vessels distributed on it, as well as with the gelatinous substance that forms the structure of Malpighi's rete mucosum.

The experiments of Jurine, of the Chevalier de Tingry, and some other philosophers, prove that there is a continual production of carbonic acid on the surface of the skin; so that it may be considered as a supplementary organ to respiration, and, under this point of view, it may be compared to mucous membranes that exhale it, and which are in contact with atmospheric air, which penetrates into the nasal sinuses and the intestinal canal, over which the membrane is expanded.

Transpiration, as elsewhere observed, is likewise a powerful medium of cooling, by the assistance of which, nature preserves the living body in an uniform degree of temperature. The water which evaporates from the whole surface of the body carries off a great quantity of caloric, and it has been observed, that every cause which augments the disengagement of this principle, produces, at the same time, a proportional increase in cutaneous and pulmonary transpiration; so that a constant equilibrium being maintained between its production and loss, animal heat must remain about the same standard.

To conclude: the extremities of nerves that terminate in the organs of our sensations are all moistened by a liquor more or less abundant, that preserves them in a state of softness necessary for the exercise of their functions. It was of equal importance that the membrane in which the sense of touch resides, should be habitually moistened by a humour passing through all its parts: this use of insensible perspiration is not of less consequence to be estimated than the preceding, to which the attention of physiologists has been principally confined.

CHAPTER V.

SECRETIONS.

Of Animal Fluids.

LXIII. THE ancient distinction of animal fluids into recrementitious, excrementitious, and excremento-recrementitious, established on the uses for which they were destined, is preferable to that proposed to be substituted in its place, by classing them according to their nature.

The first kind remain in the body, and are employed for its nourishment and its growth; as the chyle, the blood, the serum that moistens the surface of the pleura, the peritoneum, and other similar membranes. The second are expelled, and cannot longer remain in the body without injury, as the urine, the matter of insensible perspiration, and sweat. Those of the third class possess qualities of both the others, and are in part carried off while a portion remains, and serves for the support and reparation of organs, as the saliva, the bile, mucus of the intestines, &c. In the strict sense of the word, all the animal humours might be considered recremento-excrementitious. The chyle and blood, liquors highly nutritive, are loaded with heterogeneous and excrementitious parts; the urine, which of all our fluids best deserves the latter denomination, contains aqueous parts, which the lymphatics absorb, and return into the mass of humours during its residence in the bladder.

Of all the modern divisions, Fourcroy's is certainly the best; it is acknowledged by Vicq-d'Azyr to be far preferable to that which Haller published in his Physiology. Fourcroy forms six classes of humours: 1st, those which hold salts in solution, as the sweat and urine; he calls them *saline:* 2d, the *oleaginous*, inflammable fluids, which all have a certain degree of consistence and concrescibility; adeps, cerumen of the ears, &c. are of this number: 3d, *saponaceous* humours, as bile and milk: 4th, *mucous* humours, as those which lubricate the surface of the intestinal canal: 5th, *albuminous* humours, among which the serum of the blood is admitted: 6th, *fibrous* humours, as the last-mentioned fluid.

In proportion as we advance in animal chemistry, the defects of these divisions become more perceptible; for animal fluids are so infinitely compounded, that there is no one of them which may not be ranged under several of the classes at the same time, and in which the predominant element is sometimes in as great a quantity as any of the other component parts, while in the ordinary state it may form a very small portion.

Of the Blood.

LXIV. The blood is the reservoir, or common source of all the humours; but they do not exist in this liquid under the same characters by which they are characterized: they are not found already formed unless prepared by the secretory organs; they have been absorbed by the lymphatics, and carried with the lymph and chyle into the circulatory system. Let us for a moment consider its nature, without the more particular knowledge afforded by chemistry. It is red in man, and in all animals where it is warm, and even in some of those that have not a temperature sensibly different from the atmosphere (fish and reptiles): this colour, of a darker or lighter shade, taken from veins or from arteries, varies in its intensity conformably to the different states of weakness or strength. It is of a lively red in individuals full of energy and vigour, pale in dropsical subjects, and in all cases where the constitution is more or less reduced. A judgment of other qualities may be taken from its colour; in proportion to the depth of its tint, the consistence of this fluid is more viscous, its fragrant and specific odour stronger, and its saline taste more perceptible. This colour is occasioned by the presence of a prodigious number of globular particles, which flow and are suspended in an aqueous and very fluid vehicle: when the blood becomes pale, the quantity of these particles is diminished, and they seem to be dissolved in cachexies, or depraved states of the humours.

Their volume and shape have not yet been determined, even by the microscope, and it is only through the medium of this instrument that we have been able to perceive them. Lewenhoek, who has given us the idea of their surprising tenuity, estimates their bulk at the millionth part of an inch, and believed them to be spherical; Hewson said they were annular, with a central perforation; others have compared them to a flattened lentil, with a dark spot in its centre. As to other properties, they are solid, and formed with a centre, or red point, covered by a membranous vesicle, that seems to form and obliterate itself with facility.

LXV. The blood, when extracted and received into a vessel, exhales an aqueous and strongly odoriferous vapour, loses its heat, and, according to some authors (Moscati, Rosa, &c.), a gas, to the presence of which are to be attributed all its vital properties, and by this loss is reduced to a cadaverous state, on which account an analysis of the blood cannot furnish useful information, and such as might be applicable to the explanation of the phenomena of health and disease: this odour is extremely strong in carnivorous animals, and sufficiently marked in man, particularly in arterial blood. I remember retaining it a whole day in the throat, after having removed a dressing, and stopped an hæmorrhage arising from relaxation of the ligatures, a week after the operation for popliteal aneurism. If the coagulation of the blood be not prevented by agitation, its consistence augments by cooling; and if suffered to rest, it separates into two very distinct parts; one is aqueous, more or less tinged with red, heavier than common water, and perceptibly saline. This is serum, composed of water that holds in solution albumen, gelatin, soda, phosphats and muriats of soda, nitrat of potash, and muriat of lime.

Serum, though analogous to the white of an egg, is different from it, because in concreting, it forms a mass less homogeneous and solid: the albumen is evidently mixed with a portion of transparent gelatin, not coagulable by heat. The strong attraction of albumen for oxygen, gives us reason to presume that the serum absorbs this principle through the very delicate parietes of the air-vesicles of the lungs, and gives the arterial blood that frothy state which constitutes one of its distinguishable qualities. This oxydation, as well as the fixation of caloric accompanying it, likewise increases its consistence; yet it does not concrete for the following reasons: It is perpetually agitated by the circulatory powers; it is diluted by a sufficient quantity of water; animal heat never exceeds 32 or 34 degrees, and albumen is not coagulated under 50 of Reaumur's thermometer: and finally, because the serum contains a certain quantity of Soda, that furnishes it with the property of converting blue vegetable colours into green: this alkali assists in keeping the albumen in solution, for it even reduces it to a state of fluidity when coagulated by acids, alkohol, or heat.

In the midst of the serum, and on its surface, floats a red, spongy, solid mass *(insula rubra)*, that by repeated washing is separated into two very distinct parts. One is the cruor, or colouring part, which the water carries off; it is an albumen more oxygenated and more concrescible than that of serum; it holds in solution soda, phosphat of lime, with excess of iron.

The other is a solid fibrous substance; when whitened by repeated ablutions it presents the appearance of felt, the filaments of which are intersected, very extensible, and elastic. This third part of the blood is called fibrin, or its fibrous portion; it bears great resemblance to muscular fibre, and when distilled affords, like it, a great quantity of ammoniacal carbonat. Fibrin does not exist in the blood in a solid form to such an extent as might be believed; it only constitutes from $\frac{20}{1000}$ to $\frac{48}{1000}$ of the entire mass: when the blood is out of its vessels, the most animalized albumen concretes by repose, and greatly augments the quantity of fibrin.

LXVI. If blood be exposed to the action of fire, calcined, powdered, and a loadstone placed near it, thus phosphorized, the magnetic attraction demonstrates the presence of iron. Authors are not agreed as to the quantity of this metal the blood can contain. Menghini is of opinion that it constitutes $\frac{1}{100}$th part; others maintain that its proportion is $\frac{1}{303}$, which induces us to conclude that this constituent principle of the blood, like the component parts of all our liquids, may vary in quantity according to circumstances.

Blumenbach, with justice, observes that iron is only found in calcined blood, which does not possess any if suffered to pass under slow desiccation. This particularity should be no longer surprising, since Fourcroy has demonstrated that iron exists in the blood combined with phosphoric acid, and forms with it a phosphat of iron with excess of its base. This salt is decomposed by calcination; the iron remains alone, and becomes capable of being attracted by the loadstone. Physiologists consider oxydated iron existing in the blood as the cause of colour of that fluid.

At present it should be considered that the red colour of blood is occasioned by the existence of phosphat of lime, that comes into it white with the chyle, which serves it for a vehicle, and there meets with soda which dissolves and colours it; and to the oxydation of the metallic portion found in excess in this salt. It is in this solution of phosphat of lime by soda, the oxydation of superabundant iron, and the absorption of oxygen by albumen during the act of respiration, that *hematosa*, or sanguification, chiefly consists, of which the lungs constitute the principal organs.

The relative proportion of the three parts, into which the blood spontaneously separates, is very variable. It is possible for the serum to form from half to three fourths of the liquid; the colouring part and fibrin are both in an inverse ratio to the serosity; and it is observed that the more florid the colour, the greater is its fibrous portion. The pale aqueous blood of a dropsical person contains little fibrin. In putrid fever, a disease in which bleeding is absolutely contra-indicated, I have sometimes seen the blood containing very little, and very slow of coagulation; its texture seemed to participate in the affection so evidently produced on the muscular organs. In inflammatory diseases, on the contrary, the plastic power of the blood is augmented, the fibrin forms a more considerable mass; the albumen itself spontaneously coagulates, and forms a cup above the serum, which is always less abundant.

Secretions.

LXVII. It has been too generally said, that the organs receive from the blood conveyed by arteries, the constituent principles of the liquors they secrete or separate from it. We have seen that the liver offers a remarkable deviation from this general rule; the breasts also seem to form an exception, and to receive their lacteal elements from the numerous ymphatics that enter into their structure. (See the article Lactation.)

It may be affirmed, then, that the principles of our humours can be equally furnished by vessels of every kind to organs that elaborate or prepare them. The word secretion, whatever be its etymology, is used to express that function by which an organ separates from the blood the constituent parts of a humour that does not exist in this fluid, with its characteristic properties. By secretion we should not understand the simple separation of a fluid, existing before the action of the organ by which it is prepared.

LXVIII. The differences of secreted humours are visibly connected with those of the organs employed for their formation. Thus arterial exhalation, which takes place throughout the whole extent of internal surfaces, and preserves their contiguity, affords nothing but an albuminous serosity, which is only the serum of the blood slightly altered by the weak action of an apparatus of organization very little complicated. The analysis of the water in dropsy, which is merely the serosity that continually transudes the surface of serous membranes, as the pleura, or peritoneum, has demonstrated that this fluid has the greatest resemblance to the serum of the blood, and is only distinguished from it by the variable portions of albumen and the different salts kept in solution.

This first kind of secretion, this perspiratory transudation, would seem, then, to be only a simple filtration or percolation of a liquor already formed in the blood through the porous parts of arteries; yet we must here acknowledge a peculiar action of membranes, the surface of which it perpetually lubricates: without this action the serum would remain united to the other constituent parts of the blood, too warm and agitated to permit a spontaneous separation of its parts. The term exhalation given to this secretion presents a false idea of it; for exhalation is a phenomenon purely physical, which requires the presence of air to dissolve the fluid that exhales, and cannot take place on surfaces absolutely contiguous, without any interval of separation. The distinguishable character of this kind of secretion is the absence of any mediate structure between the *vas afferens* and the excretory duct: the minute arteries and veins that enter into the texture of membranes also constitute both.

LXIX. After serous transudation, requiring only a very simple organization, follows the secretion effected by cryptæ, glandular follicles, and mucous lacunæ. Each of these small glands contained in the texture of membranes lining the internal surface of the digestive, arterial, and urinary passages, in which, when conglomerate, form amygdalæ, &c. may be compared to a small bottle, the bottom of which is round, and the neck short: the membranous parietes of these vesicular cryptæ are supplied with a great quantity of vessels and nerves. It is to the peculiar action of these parietes that the secretion of mucus by these glands should be attributed. These mucous liquids are less fluid and more viscid than the serum produced by the first kind of secretion, but contain more albumen and salts, are more different from the serum of the blood, and of a more excrementitious nature: the fundus of these bottle-like glands is turned towards the parts to which the mucous membranes adhere; their mouth or neck opens on the surface contiguous to these membranes. This species of excretory ducts, variable in diameter, always very short, sometimes unite together, and open by one common orifice on the internal surface of cavities. These apertures, by which several mucous glands discharge themselves, are easy to be perceived on the amygdalæ, in the mucous lacunæ of the rectum, urethra, base of the tongue, &c.; the albuminous liquor that is poured on the internal part of these glandular cryptæ, remains some time in their cavity, and thickens by the absorption of its fluid parts, for lymphatics also exist in the texture of their coats: when the surfaces they surround have occasion to be moistened, the small sac contracts, and expels the liquor with which it was distended. Secretion and excretion are facilitated by the irritation occasioned by the presence of the air, aliment, or urine; by the compression induced by them; and, finally, by the peristaltic contractions of the muscular structure, to which mucous membranes adhere throughout the whole extent of the primæ viæ.

LXX. The fluids which are considerably different from the blood, require for their secretion organs of a more complicated structure; these are called *conglomerate* glands, to distinguish them from lymphatic glands, which are named *conglobate*. These glands are visceral masses, formed by an assemblage of nerves and every species of vessels, disposed in packets, and united by cellular structure: a proper membrane, or an elongation of that which lines the cavity that includes them, surrounds their external surface, and separates them from circumjacent parts.

The peculiar and minute structure of different parts that enter into the composition of secretory glands, the manner in which arteries, veins, and nerves, are distributed, and in which the lymphatics and excretory ducts arise, have been the subject of endless discussion, and formed the basis of ancient physiological theories. Every thing that has been well attested may be reduced to the following particulars:

The respective or relative disposition of similar parts that enter into the structure of glands, and form their proper substance *(parenchyma)* in each of them; which explains the varieties they present under the double relation of their properties and uses.

The arteries do not form an immediate continuation with their excretory ducts, as Ruysch affirmed; nor do there exist intermediate glands between these vessels, as Malpighi believed: it seems more probable that each gland has its cellular or parenchymatous texture in the areolæ, into which the arteries pour the materials of the fluid they prepare, in consequence of a power peculiar to them, and which forms their distinguishing character. Lymphatics and excretory ducts arise from the sides of these little cells, and both these species of vessels absorb; one attracts the secreted liquor, carrying it into receptacles, where it accumulates, while the other receives that part which the action of the organ could not completely elaborate, or the residue of the secretion.

LXXI. The nerves, which always enter more or less into the structure of secretory organs, and come principally from the great sympathetics, terminate variously in their substance, and furnish each of them with a particular sensibility, by means of which they distinguish *(ils reconnoissent)* in the blood brought thither by the vessels the constituent parts or materials of the humour they are destined to prepare, and select it by a real preference. Besides, they cause them to take on a peculiar mode of activity, the exercise of which causes these separate elements to undergo a certain composition, and impresses the fluid produced with specific qualities, always relative to the mode of action of which they are the result. Thus the liver retains the constituent principles of bile contained in the blood of the vena portæ, elaborates, combines them, and forms the bile, an animal fluid distinguishable by certain characteristic properties that are subject to variations, according as the blood contains the elements which enter into its composition, in a greater or less degree, according to the increased or diminished disposition of the gland to retain them, and to effect a more or less complete mixture of them. The qualities of the bile, dependent on the concurrence of all these circumstances, should present so many differences as the blood contains principles, and as the hepatic organ may offer varieties relative to the composition of the former, and degree of activity in the latter. Hence arise alterations of the bile, the most inconsiderable of which being compatible with health, escape observation, while those which are more complete, and derange the natural order of the functions, become evident by diseases, of which they may be sometimes considered the effect, and at other times the cause. These alterations of the bile (and what is here said of the secretion of this humour may extend to almost every other secretion of the animal economy) never extend so far as to prevent it from being distinguished; it always preserves, in a greater or less degree, its essential and primitive characters; it never acquires the qualities of another liquor, so as to resemble semen, urine, or saliva, &c.

The action of secretory glands is not continual; most of them are subject to the alternate state of action and rest; all, as Bordeu observed, are asleep or awake when any irritation operates on them or in their vicinity, and determines their immediate or sympathetic action. Thus saliva is secreted in greater quantity during mastication; the gastric juice is only poured on the internal surface of the stomach during digestion in that organ; when the stomach is empty the secretion ceases, and is renewed when the introduction of other aliment shall have produced a necessary degree of irritation. The bile flows in greater abundance, and the gall-bladder empties itself of its contents during the distention of the duodenum by the chyme, &c.

When a secretory organ enters into action, it draws into motion the surrounding parts, or such as are situated in its vicinity (Bordeu). It is said that a part is in the department of this or that gland, when it participates in the motion by which the organ is agitated during the time that the secretion is carried on, or when it contributes to some purpose relative to the action of the gland: these departments are of greater or less extent, according as the action of glands is more or less important. Thus it may be said that the spleen and a great number of viscera of the abdomen are of the department of the liver, because it receives the blood from them which it is destined to organize; the liver is also comprised in the sphere of activity of the duodenum, since the repletion of this intestine irritates it, determines a more abundant afflux of humours, and a more copious secretion of bile.

LXXII. The blood conveyed to a secretory gland, before it arrives there suffers preparatory changes, which dispose it to furnish the constituent principles of the liquor about to be secreted. We have seen, in the chapter on digestion, how proper the blood, carried to the liver by the vena portæ, is rendered for the secretion of bile. There is no doubt but that the portion of this fluid conveyed to the testicle by the long, slender, and contorted spermatic arteries, in passing through these vessels, experiences modifications which occasion it to be more like the spermatic liquor, &c.

The celerity with which the blood arrives at an organ, the length, diameter, direction, angles of the vessels, and the disposition of their ultimate ramifications, which may be stellated, as in the liver; resembling asparagus, as in the spleen; contorted, as in the testicle, &c.; are all circumstances which ought to be considered in the examination of each secretion, since they have an influence on the nature of the secreted fluid, and on the mode in which secretion is effected.

The liquor that lubricates the whole extent of surfaces of motion, by which the different parts of the skeleton are united, is not exclusively prepared by the membranous capsules that surround the articulations: several red cellular masses, situated in the vicinity, cooperate in this secretion. Although these cellular fasciculi, long looked upon as synovial glands, have not a perfect resemblance to conglomerate glands, and although neither glandular bodies nor excretory ducts can be demonstrated, yet we must consider them as supplying those functions to a certain degree, and admit that they are of some utility in the secretion of synovia. Their existence is constant, their number and size always proportioned to the extent of the articulating surfaces, and the frequency of motion performed by the articulations. They are found in all animals to be paler after long rest; red, highly vascular, and present marks of inflammatory orgasm in those which, just before death, had been forced to travel a great distance, as oxen that come to Paris from the distant provinces, and deer that have been followed a great distance by the hunters. In anchylosis they are not so red, but thicker than in a natural state.

Do not the humours, when attracted by the irritation in consequence of friction, and which flow from every part towards an articulation, experience a particular modification in passing through these glandulo-cellular masses, which renders them better adapted to the secretion of synovia? This would not be the only example of parts in the human body, the action of which is only secondary, and concurring with that of other organs particularly destined for a secretion, the constituent parts of which are contained in the blood passing through them. It will be, doubtless, objected to this doctrine, that such a preparatory apparatus is not found in the vicinity of great cavities; but two things are not identical to be analogous; independent of the chemical nature and uses of the synovia being not exactly the same as those secreted by the pleura or peritoneum.

LXXIII. When a gland is irritated it becomes the centre of fluxion, towards which humours flow from every part in the vicinity; it swells, becomes hard, contracts, has a kind of erection, and acts on the blood brought by its vessels. Secretion, dependent on a peculiar power inherent in a glandular organ, is assisted by the motions of surrounding muscles. The light pressure which these parts make on glandular organs is sufficient to keep up their excitement, and to assist the secretion and excretion of the fluid. Bordeu, in his excellent work on glands and their action, has clearly proved it is not by compression, made by the neighbouring muscles, that glands discharge the liquor they have separated; and that those physiologists were in an error who affirmed that the *excretion* of a liquid was merely its *expression*, and thus compared glands to a sponge soaked in a fluid, which was evacuated on compression.

The excretory ducts of organs absorb or reject the secreted liquor according as it may affect their inhalant orifices; these canals participate in the convulsive state of the gland, shorten themselves, and contract on the fluid to propel it forwards. In this manner the saliva sometimes jets out of Stenon's duct (the excretory duct of the parotid gland) at the sight or remembrance of food that is particularly palatable or savoury; thus the vesiculæ seminales and urethra (for the reservoirs in which the humours remain for a space of time before their evacuation should be considered as forming a part of excretory ducts) contract, erect, and elongate, to project the spermatic liquor to some distance.

The fine and transparent ureters of birds have been seen to contract on the urine, which in these animals concretes in consequence of the smallest stagnation.

The glands, after having remained for a longer or shorter time in this state of excitation, relax, become collapsed, and fluids are not conveyed to them in such abundance: they remain in a state of quiescence, or sleep, and during repose renew their sensibility, which is consumed by long exertion. It is a known fact, that a gland too long stimulated, like every other part, becomes insensible to the stimulus, the protracted application of which fatigues and overcomes it.

The multitude of secretory organs constantly occupied in separating different humours from the blood would very soon exhaust it, if the calculation of physiologists on the quantity that each gland can supply were not evidently exaggerated. In fact, if we admit with Haller, that the mucous glands of the primæ viæ secrete eight pounds of mucus in twenty-four hours, and that the kidneys separate four pints of urine in the same time, that an equal quantity is evacuated by insensible perspiration, and as much by pulmonary transpiration; we shall daily lose twenty pounds of fluid, almost totally excrementitious; without including bile, saliva, or pancreatic juice, which, in part, enter into the blood, after having been separated from it, or the serum which moistens internal surfaces, and is entirely excrementitious.

Another very remarkable circumstance in secretions is, that they mutually replace and supply each other; so that when the urine is less copious, perspiration is more abundant, and *vice versa*. A sudden coldness of the skin frequently occasions obstinate diarrhœas; the humours are immediately repelled towards the intestinal canal, and pass off by the mucous glands of the intestines, the action of which is considerably increased.

LXXIV. Certain bodies have been ranged among the order of glands, the appearance of which is truly glandular, but the use altogether unknown. Thus the thyroid and thymus glands, parenchymatous organs, destitute of excretory ducts, although they receive many vessels and some nerves, do not seem to secrete any liquid. But may not the blood, which is carried in such abundance to the thyroid gland, suffer certain modifications that do not the less exist for not having been discovered? May not the lymphatic vessels likewise supply the office of excretory ducts, and convey the fluid elaborated by this glandular body in a direct course into the mass of blood? The seminal capsules (*gubernacula*) are in a similar situation; but they have an internal reservoir, a kind of lacuna, the parietes of which are covered by a viscous brownish coat, secreted by the capsule, and doubtless carried into the mass of blood by the lymphatics arising from the sides of its internal cavity.

The Secretion of Fat by the cellular Structure.

LXXV. The delicate cellular texture extending through every part of our body serves to envelop all our organs; it is not only employed to separate one from the other, to unite their different parts, and maintain an universal connexion; it is also the secretory organ of the adeps, a semi-concrete, oleaginous, animal liquor, found in almost every part of the body deposited in numerous cells. The membranous parietes of these small cellular cavities receive a great number of small arteries, in which the adeps is separated, carried by its specific lightness to the circumference of the column of blood in these minute vessels, and transudes through the apertures by which the parietes of these cells are perforated. Its quantity, like its consistence, varies in different parts of the body, and in different individuals; there exists a thick layer of it under the skin (panniculum adiposum); it is found in great abundance in the interstices of muscles, in the direction of blood-vessels, in the vicinity of articulations, around certain organs, as the eyes, kidneys, and breasts: that which fills the bottom of the orbital cavity and surrounds the eyeball, is soft and almost fluid; that which is deposited about the kidneys and great articulations, on the contrary, has the consistence of suet. There exist several degrees between these extremes, and it may be said that the animal oil or fat of which we now speak, is not exactly alike in two different parts of the body; the temperature of a living body keeps it in a state of semi-fluidity, as we may be daily convinced in the practice of surgical operations.

In certain parts it is even absolutely liquid; but it has been observed that its nature is essentially altered; it then no longer contains oil, and does not differ from a simple aqueous gelatin: thus the fluid which distends the cells of the palpebræ, the coverings of the testicle, &c. has been considered by several physiologists as absolutely different from adeps. It is necessary to observe, that the laminæ of spongy texture are more extensile in these parts, present a greater surface, form membranous expansions, and circumscribe larger cells, so that the differences of secretions are perfectly conformable to the varieties of structure.

In an adult man of moderate rotundity, the adeps constitutes a twentieth part of the weight of the body: it is proportionably more abundant in children and females; for its quantity is always relative to the degree of energy of the assimilating functions. When digestion and absorption are carried on with activity, fat accumulates in the cellular texture; and if we consider that its nature is not much animalized; that it has a more striking analogy to oils drawn from vegetables; that it contains very little azot, and a great quantity of hydrogen and carbon, like all oleaginous bodies, since it is decomposed by distillation into water and carbonic acid, giving off a small portion of ammoniac; that its proportion may vary *ad infinitum;* that it can be considerably augmented or diminished, without the order of functions being visibly deranged; that animals which pass a great part of their time in long abstinence, seem to exist during this state of torpor on the fat before accumulated in different parts of their body; we shall be very much induced to believe, that the state of fatness is a kind of *intermedium* for a portion of the nutritive matter extracted from the food, through which it must necessarily pass before it is assimilated to the individual of which it is destined to repair the loss. Animals that feed on grain and vegetables are always fatter than those which live exclusively on animal food.

The dormouse and mountain rat acquire a surprising corpulency during the autumnal season, then retire into their subterraneous holes to remain six months in winter without provision, and exist on the fat with which all their organs superabound: it is chiefly found in the abdomen, where the omentum forms a very large adipose mass. At the commencement of spring, when the state of torpidity ceases, and they revive from their long sleep, they are generally reduced to a degree of extreme marasmus.

A corpulent man suddenly restrained in diet becomes visibly thinner in a short space of time: the size and weight of the body diminish by the absorption of fat which supplies the deficiency of aliment. It may then be considered as a *corps de reserve*, by means of which nature always finds materials to supply daily consumption, notwithstanding the diminution of food, and consequent deficiency of its nutritive qualities.

LXXVI. The fat does not serve to absorb acids formed in the animal economy, as advanced by Macquer; that which is extracted from it by distillation *(sebacic acid)* is a new product, resulting from a combination of the oxygen of the atmosphere with hydrogen, carbon, and a little azot found in it: the small quantity of this latter principle almost converts it into a vegetable acid. Fat has a powerful attraction for oxygen, and becomes rancid by possessing it after remaining long exposed to the air. It separates this principle from metallic oxyds, at the same time that it facilitates the oxydation of metals by trituration. Its density augments in proportion as it absorbs this element: thus oils, in oxydating, become solid, and fats acquire a consistence resembling wax, which, in fact, is only an adipose body, strongly impregnated with oxygen.

Independent of the principal use assigned to the fat, and for which we may consider the cellular system as a vast reservoir, in which a great quantity of nutritive, semi-animalized matter is found deposited, this liquor has also several secondary purposes; it preserves the heat of the body, because, like the cells in which it is deposited, it is a bad conductor of caloric. It is a known fact, that excessively fat persons scarcely feel the cold of a severe winter. The adeps, by its unctuous qualities, facilitates the contraction of muscles, the motion of all the organs, the gliding of their respective surfaces; it also supports the skin, fills up vacuities, and gives the limbs that soft contour and elegant form represented in the figure of a woman; and, finally, it covers and surrounds the extremities of the nerves, diminishing their susceptibility, which is always in an inverse proportion to corpulency. This circumstance induced an eminent physician to say that the nervous tree, planted in the adipose and cellular system, would suffer when the branches, by the diminution or obliteration of this texture, were too much uncovered, and exposed to the action of external objects, that would be as prejudicial to them as the rays of the sun to the roots of a vegetable torn out of the earth in which it was growing. In fact, it is observed that persons subject to nervous affections constantly join an extreme leanness to an excessive sensibility.

LXXVII. According to the doctrine of modern chemists, fat is employed for the dehydrogenation of the system. When the lungs or the liver are diseased, and respiration or biliary secretion does not carry from the heart so great a proportion of this oleaginous and inflammable principle, fat is formed in greater abundance. They support their argument on the result of the following experiment, that consists in shutting up a goose, the liver of which is to be fattened, in a narrow cage, situated in a warm and dark place, in feeding it with a nutritious paste: the animal becomes more ravenous after this food when deprived of locomotion, from an endeavour to exercise the organs of motion by this action of digestion. Notwithstanding this excess of nourishment, the bird loses flesh, and falls into a state of marasmus, its liver softens, becomes oleaginous, and acquires a surprising magnitude.

This experiment, like many other facts, proves that secretions give rise to productions which have great analogy, and mutually supply each other. But may the chemical theory be admitted on the functions of the fat, if we recal to memory that in individuals of the greatest corporeal rotundity, respiration and the secretion of bile are completely effected without any obstacle; but that difficult respiration in pulmonary consumption, and impeded biliary secretion in cases of hepatic obstruction, are always accompanied with the most complete marasmus?

Every thing which serves to moderate the activity of the circulatory system has a tendency to introduce adipose plethora. Thus a too long repose of body and mind, very copious bleedings, and castration, sometimes produce *polysarcia*, an affection in which the cellular organ seems in a state of atony, and suffers a true deposition of adeps analogous to a steatomatous tumour. If the energy of the heart and arteries be too great, leanness is the inevitable consequence; on the contrary, when the sanguiferous system becomes languid, a gelatinous adeps only is formed, and that rotundity of the body called bloatedness.

This fluid, not well elaborated, which distends the parts in truly phlegmatic habits, is but an imperfect kind of fat: it resembles marrow, a very fluid adeps, the consistence of which diminishes when animals lose flesh. The marrow, inclosed in the cells of the cancelli of bones, cavities which cannot contract, but remain always of the same dimensions, never leaves them empty, although it has a greater or less degree of density; and what authors have said concerning a diminution of quantity, should rather be understood to relate merely to its consistence.

CHAPTER VI.

NUTRITION.

LXXVIII. ALL the functions that have hitherto been the object of our attention; digestion, by which alimentary substances introduced into the body are deprived of their nutritive parts; absorption, which carries this nutritious extract into the mass of fluids; and the circulation, by which it is conducted towards parts where it is to undergo various degrees of depuration: digestion, absorption, circulation, respiration, and the secretions, are only actions which are preliminary and preparatory to the more essential function which makes the object of this chapter, the demonstration of which will complete the history of assimilating phenomena.

Nutrition may be considered the completion of assimilating functions. The food, changed by a series of decompositions, animalized and rendered similar to the being which it is designed to nourish, applies itself to those organs, the loss of which it is to supply, and this identification of nutritive matter to our organs constitutes nutrition.

The living body is continually losing its constituent parts, which a variety of causes are incessantly carrying off; several of its organs are constantly engaged in separating humours which pass off loaded with a part of its substance, consumed by the united action of air and caloric: internal friction, agitated by a pulsatory motion, detaches its particles.

Thus the animal machine is continually destroyed, and at distant periods of life does not contain a single particle of the same constituent parts. An experiment made with madder (rubia tinctorum), which, when mixed with the food, reddens the bones of animals, proves in a very decisive manner this perpetual decomposition of living animal matter: entirely to obliterate the diffused red colour of bones, it is only necessary to suspend, for a time, the use of this root. Therefore, if the most compact and solid parts be in a continual motion of decomposition and recomposition, there can be no doubt but that this motion must be more rapid in those parts, the constituent principles of which are in the smallest degree of cohesion, as in fluids.

It has been an object of consideration to determine the period of the entire renovation of the body; it has been said that an interval of seven years was necessary for the same particles to be totally obliterated, and their place supplied by others; but this change should seem to be more rapid in infancy and youth; it should also seem to be retarded in manhood, and require a very long time to be accomplished in old age, when all our parts acquire a remarkable degree of consistence and fixity, at the same time that the vital actions become more languid. There is no doubt but that sex, temperature, climate, profession, mode of living, and a variety of other causes accelerate and retard this period, so that it is impossible to affirm any thing certain on the precise time of its duration.

In proportion as our parts are destroyed, they are renewed by homogeneous particles, or such as are exactly similar to themselves; otherwise their nature, which is always alike, would suffer continual changes.

When the nutritive matter has been animalized or assimilated to the body which it is designed to nourish by the organs of digestion, absorption, circulation, respiration, and secretion, the parts which it supplies retain and incorporate it with their own substance. This nutritive identification is variously effected in different parts, as the brain, muscles, bones, &c.; each of these appropriates to itself, by a true secretion, that which is found analogous to its nature, and rejects the heterogeneous particles brought by different vessels, chiefly by the arteries. A bone is a secretory organ that becomes incrusted with phosphate of lime; the lymphatic vessels, which, in the work of nutrition, perform the office of excretory ducts, remove this salt after it has remained a certain time in the areolæ of its texture. It is the same in muscles with respect to the fibrin, and in the brain with albumen: each part imbibes and renders solid in its structure such juices as are of the same nature, in consequence of a power, of which the affinity of aggregation of the chemists gives us an idea, and perhaps furnishes us with an exact model.

A part to acquire nourishment should possess sensibility and motion: a ligature placed on its arteries and nerves, by destroying both these faculties, prevents it from being nourished or having life. The blood flowing in the veins, and the fluid of the absorbents, contain vivifying and reparatory parts in much smaller quantity than arterial blood: it is even generally believed that lymph and venous blood do not contain any thing directly nutritious.

LXXIX. The mechanism of nutrition would be explained after having precisely determined the differences of composition that exist between the aliments on which we exist and the exact substance of our organs, if we could distinguish how each function divests them of their characters, to invest them with our properties for each individual part, to cooperate in changing their nutritious principle into our own peculiar structure. To resolve this problem, let us suppose a man living entirely on vegetables, which, in fact, constitute the principal part of the subsistence of the generality of men; whatever portion of the plant he may consume, whether stalk, leaves, flowers, seeds, or roots; carbon, hydrogen, and oxygen enter their composition, which may be always, by a strict analysis, resolved into water and carbonic acid: to these three constituent principles, sometimes a small quantity of azot, salts, and other things, is united. If we then examine the nature of the organs of this man, whose diet consists exclusively in vegetables, they will be proved of a composition very different from the kind of food; azot predominates, although the vegetable substance contain it in very small quantity, and many new products will be discovered which had not been distinguished in the aliment, but which abound in the body receiving nourishment, and seem produced by the act of nutrition.

The essential part of this function, therefore, is to cause the nutritive matter to pass into a more advanced state of composition, to deprive it of a portion of its carbon and hydrogen, to give a predominance of azot, and develop several substances which were not before distinguishable. Every living body, without exception, seems to possess the faculty of forming and decomposing substances, by the assistance of which it is supported, and of giving rise to new products. The marine plant, the ashes of which form soda, if sown in a box filled with earth that does not contain a particle of that alkali, and moistened with distilled water, furnishes it in as great a quantity as if the plant had been growing on the borders of the sea, in a swampy soil, always inundated by brackish or salt water.

Living bodies, then, are the proper elaboratories in which such combinations and decompositions occur as art cannot imitate: bodies that to us appear simple, as soda and silex, seem to form themselves of other parts, while some bodies, the composition of which we cannot determine, as certain metals, suffer inevitable decompositions; from which we may fairly conclude, that the powers of nature in the composition and decomposition of bodies far surpass the science of chemists.

For a substance to be employed in our nourishment, it should be capable of change and fermentation, that is susceptible of experiencing an internal and spontaneous motion, by which its elements change their combination and qualities. This condition of spontaneous mutability excludes from the class of aliment every thing which is not organized, or constituted part of a living being: thus minerals are absolutely refractory to the action of our organs, which cannot convert them into their own peculiar substance. The common principle drawn from alimentary substances, however various they may be, called by Hippocrates the aliment, is probably a composition capable of a great degree of change and fermentation: this is also the opinion of all those who have endeavoured to discover its nature. Lorry thinks it is a mucous body; Cullen considered it saccharine; Hallé believes it to be an hydro-carbonated oxyd, which only differs from the oxalic acid by having a smaller portion of oxygen. It is obvious that these three sentiments have the greatest resemblance, since oxygen, carbon, and hydrogen, united in different proportions, form a mucous, a saccharine body, and the oxalic base. The analysis of animal substance by nitric acid reduces it to the latter base by taking from it a great quantity of azot, the presence of which constitutes its most remarkable character.

LXXX. Hallé believes that the hydro-carbonated oxyd is combined with oxygen in the stomach and intestinal canal, whether the latter principle be introduced with the food into the primæ viæ, or furnished by the decomposed humours; the intestinal fluids suffer their azot to be disengaged, which is carried to the alimentary base, and replaces the carbon that had been attracted by the oxygen to form the carbonic acid. This gas when in the lungs, and again subjected to the action of atmospheric oxygen, carries off a certain portion of its carbon; and as it disengages the azot from venous blood, it effects a new combination of this principle with the chyle; and when propelled to the skin, the atmospheric oxygen again disengages its carbon and completes its azotification: perhaps even the cutaneous organ answers similar purposes to the lymphatic system, as the pulmonary organ may effect to the sanguiferous system.

The animalization of alimentary substance therefore takes place principally by the loss of its carbon, which is replaced by azot in animal fluids; these support themselves in a proper state, for, as they are continually losing the carbonic principle in the intestinal, pulmonary, and cutaneous combinations, they would be too much animalized if a newly-formed chyle were not to attract the excess of azot. This theory is admitted by its author not to account for the formation of phosphoric salts, adeps, and abundance of other productions; but without adopting it *in toto*, we are induced to conclude, from the experiments and observations on which it is established, that the oxygen of atmospheric air is one of the most powerful agents employed by nature to convert the aliments on which we subsist into our own peculiar substance.

The proportion of oxygen and carbonic acid contained in the intestinal canal diminishes from the stomach towards the large intestines, while, on the contrary, that of azot increases. Hydrogen is more abundant in the large than in the small intestines; it is found to exist in less quantity in the latter than in the stomach.—Jurine, *Analyse de l'Air que contenoit le Tube digestif d'un Maniaque.*

CHAPTER VII.

SENSATIONS.

LXXXI. TO form an accurate knowledge of the mechanism of the action of external objects on our body, we must follow the natural succession of the phenomena of sensation or feeling, by first considering the body that produces the *sensitive impression*, then by examining the organs that experience that impression, and afterwards the conductors which transfer it to a particular centre destined to perceive it. Take the sense of sight as an example: we should never be able to know the manner in which light acts to procure us a knowledge of certain qualities of bodies, if ignorant of the laws to which this fluid is subservient, if we had no idea of the conformation of the eye, of the nerves which establish a communication between those organs and the brain, nor of this viscus itself, to which sensations, or rather motions which constitute them, are conveyed.

On Light.

LXXXII. The greater number of philosophers at present consider light as a fluid, of which the extreme subtility renders it impalpable; some think that it is only a modification of caloric, or matter of heat, and this opinion has acquired great probability since the late observations of Herschel.

This celebrated astronomer has just published in the Philosophical Transactions of the Royal Society of London, for the year 1800, a series of experiments, proving that the rays of light, variously coloured, give different degrees of heat to bodies to which they are directed; and that the red ray, which admits of the least refraction, affords the most heat.

We shall not here examine whether light, as considered by Des Cartes and his followers, be composed of round particles, existing by itself, uniformly expanded through space; or whether, as generally believed since Newton, that it is only an emanation from the sun and fixed stars, which dart on all sides a portion of their substance, without being exhausted by this continual effusion. It is sufficient to know, 1st, That the rays of this fluid move with such celerity, that light, in a second, can be conveyed 216,000 miles; since, according to the calculations of Roëmer, and the tables of Cassini, it travels in seven or eight minutes thirty-three millions of leagues, which is the distance between this earth and the sun. 2d, That light is called *direct* when it comes from a luminous body to the eye without meeting any obstacle; *reflected*, when it is transmitted to this organ through an opake body; *refracted*, when its direction has been changed by passing through transparent media of unequal density. 3d, That a luminous ray is reflected in a direction equal to the angle of incidence; that the ray passing through a transparent body, or one permeable to light, suffers a stronger deviation in proportion to its approximation to the perpendicular line, the convexity of the surface of the body, or its degree of density. 4th, That a ray of light, refracted by means of a prism, is decomposed into six rays, which are, red, orange, yellow, green, purple, and violet. When a lighted body reflects all these rays, the sensations they might separately produce are all confounded in the sensation of white; if it should only reflect certain parts, the body appears variously coloured agreeably to the rays which emanate; finally, if all be absorbed, there arises the sensation of blackness, which is a destruction of all colours. A black body is enveloped in utter darkness, and is only perceptible by the brightness of surrounding bodies. 5th, From each point of the surface of a luminous body a great number of rays are sent off, which diverge with a force progressively decreasing, so that the rays, separating more from the perpendicular in proportion to their distance from their source, or the body from which they are reflected, form cones, the apices of which are on all the visible points of a body, and the bases rest on the anterior part of the eye which perceives them. 6th, Finally, the force with which a transparent body approaches the perpendicular line, the rays of light which pass through it, is not only in direct ratio of its density, and greater or less convexity, but it has also a relation to the combustible nature of the body. Those substances which can burn are, *cæteris paribus*, more powerful refractors than incombustible bodies. It is from this curious experiment that Newton conjectured the combustibility of the diamond, and the existence of a combustible principle in water, since his time clearly elucidated by the experiments of modern chemistry.

The Sense of Sight.

LXXXIII. The eyes, in which this sense resides, situated in an elevated part, command a great number of objects, and are inclosed in two bony cavities, known by the name of *orbits*. The base of these cavities turned forwards is obliquely cut outwards, so that their external part not being so long as the others, the globe of the eye, supported on this side only by soft parts, can be directed outwards, and obtain a knowledge of lateral objects without changing the situation of the head. In proportion as we descend from man in the scale of beings, the division of the base of the orbital fossæ becomes more oblique; the eyes cease to be directed forwards; finally, the external parietes are less; sight is directed entirely outwards; and as it is from the eyes that physiognomy draws its principal character, this character is absolutely changed. In certain quadrupeds of great swiftness, as the hare, the lateral situation of the organs of sight prevents the animal from seeing any small body directly forwards; for which reason, when closely pursued, they so easily fall into snares.

The ogan of sight is formed of three parts perfectly distinct, which serve to protect the globe of the eye, to withdraw it suddenly from the influence of light, and to preserve it in a condition necessary for the exercise of these functions: these consist in the *supercilia*, *palpebræ*, and *lachrymal* passages, parts accessory to the organ. The eyeball itself presents two portions very different from each other, one formed by almost the whole, and may be called an optic instrument, an object placed before the retina, employed to make the rays of light undergo changes that are indispensable in the organ of vision; the other, formed by a medullary expansion of the optic nerve, is the immediate organ of this function: this is the retina, alone adapted to receive the impression of light, and to be affected by the delicate contact of this extremely subtile fluid. This impression or sensation is transmitted to the cerebral organ by the optic nerve, of which the retina is merely the expanded extremity.

The Supercilia, or Eyebrows; Palpebræ, or Eyelids; and lachrymal Passages (Tutamina Oculi, Haller.*)*

LXXXIV. The darker or lighter colour of the hair of the supercilia renders this projection well adapted to diminish the effect of a too strong light, by partly absorbing its rays. The supercilia answer this purpose better in proportion to the projection formed and the darker colour of the hair: thus we knit the brow transversely when passing from a dark to a lighted place, the strong light of which has a disagreeable effect on the organ of sight. Hence arose the custom of certain southern people, in whom the eyebrows are thicker and of a darker colour, to make them blacker, in order the better to fulfil the intention for which they were designed.

The palpebræ are two movable coverings expanded before the eye, which they alternately cover and uncover; they should be extensible and capable of great mobility: both these advantages are offered by the tarsal cartilages stretched over the whole length of their movable margin, and by the muscles which enter into their structure. The cellular texture that unites the fine and delicate skin of the eyelids to the muscular fibres, contains a gelatinous lymph, the easy accumulation of which gives rise to œdema of the eyelids, instead of an adipose substance which might have impeded its motions. The structure of the eyelid is not entirely opake; for when they are totally closed, and completely cover the globe of the eye, the luminous appearance of day can be distinguished from the darkness of night.

The principal use of the eyelids is to shade the eyes from the continual action of light: these, like all other organs, have occasion for repose, which could not have been procured had the rays of light constantly excited their sensibility. A removal of the eyelids occasions loss of sleep.

This kind of punishment was used by the ancients. The Carthaginians made use of it to punish the magnanimous heroism of Regulus. (See Plutarch's Lives of illustrious Men.)

The humours soon flow towards this organ, now become painful in consequence of continual irritation; the eyes inflame, the inflammation augments, is carried to the brain, and the person expires amidst the most excruciating torments. Thanks to the progress of civilization, these barbarous punishments have been long abolished, and the necessity of the existence of these parts is proved by the inconvenience arising from the lower or tarsal margin being turned up, so as to leave a small part of the cornea or sclerotic uncovered. The part exposed to the continual action of the air and light becomes irritated and inflamed; thence arises an ophthalmia, which is not cured until the margins are brought into mutual contact by a surgical operation, since their separation was the cause of the disease. Small curved hairs of the same colour as the eyebrows arise from the tarsal margins of the eyelids; they are called *cilia*, and are destined to prevent insects or other light bodies in the atmosphere from insinuating themselves between the globe of the eye and its coverings.

The anterior part of the eye, thus defended against external injuries, is continually moistened by the tears. The secretory organ of this liquid is a small gland, situated in a cavity on the anterior and external part of the orbit, surrounded by adeps, receiving vessels and nerves in proportion to its size. The fluid secreted in this gland passes through seven or eight ducts, which open on the internal surface of the superior palpebra, and are directed downwards and inwards. The tears constitute a mucoso-serous liquid, a little heavier than distilled water, inodorous and saline, changing the colour of blue vegetables into green: it contains soda, muriat, carbonat of soda, and a little phosphat of soda and of lime.

In ophthalmia, the irritation of the conjunctive membrane, transmitted by sympathy to the lachrymal gland, not only augments the quantity of its secretion, but also seems to alter the properties of the liquid secreted. Do not the tears, which, in this affection, flow so abundantly, and occasion the sensation of a burning heat on the inflamed parts, contain a greater proportion of fixed alkali than is found in its usual state? and do not the pains depend at least as much on this superabundance of soda, as on the increased sensibility of the membrana conjunctiva?

This membrane is only an expansion of the skin covering the internal surface of the eyelids, become extremely fine, and reflected over the anterior surface of the eye, which also unites that part to the eyelid. An albuminous serum exudes from the whole of its surface, mingles with the tears, and augments the quantity of fluid.

> The skin is not perforated at the part corresponding to the globe of the eye; it is continued to the transparent cornea, to which it adheres so firmly that it is with difficulty detached. In certain animals destitute of eyelids, the skin is continued over the globe of the eye without diminishing in thickness: the conjunctive (if it may be so called) being opake, renders the globe of the eye, imperfect in other respects, entirely useless. This formation exists in a species of eel called *murenà cæcilia* by the naturalists: the *gastrobranchus cæcus* is deprived of sight in a similar manner.

The tears are equally expanded over the surface of the globe of the eye by the alternate motions of the palpebræ, the friction of which is obviated by this fluid, which also prevents the organ of sight from being made dry by the contact of the air, that dissolves and carries off by evaporation a part of this fluid. This evaporation of the tears is well proved by the weeping or effusion of liquid from the eyes of persons in whom this humour is copiously secreted, so often as the atmosphere, being too humid, does not dissolve it in sufficient proportion. The adipose, oleaginous humour secreted by the glands of Meibomius, moistens the tarsal margins of the eyelids, prevents the tears from falling on the cheek, and serves the same purpose as greasy bodies rubbed on the edges of a vessel filled above its brim, to prevent it from overflowing.

The greater part of the tears flows inwards, towards the internal angle of the palpebræ, carried in this direction by the natural closing of their movable margins; by the triangular opening behind the contact of these edges, the round and convex surfaces of which touch only at a point; and also by the action of the palpebral portions of the orbicularis muscle, the fibres of which taking their fixed point at the internal angle of the orbit, into which part the tendon is inserted, always draw their external commissure inwards.

The tears, when carried to the internal angle of the eye, accumulate in the *lacus lachrymalis*, a small space formed by the distance of the margins and the *caruncula lachrymalis:* the latter body, long considered by the ancients as the secretory organ of the tears, is merely an assemblage of mucous cryptæ, loosely covered by the conjunctive membrane. These folliculi, of the same nature as Meibomius's glands, also secrete a thick oleaginous humour, which moistens the loose margins of the eyelids in the vicinity of the internal commissure. At this part the edges required a thicker covering; the tears there accumulated have, in no part, a greater tendency to escape down the cheek.

Near the union of the horizontal with the curved portion of the palpebræ, at the internal angle arise two small tubercles, perforated at the top by an orifice: these orifices are called *puncta lachrymalia*, distinguished into superior and inferior, like their corresponding eyelid. These puncta, when examined in the dead body, do not appear tuberculated: the small eminences, doubtless produced by a state of orgasm and vital erection, collapse at the approach of death. These small apertures, directed inwards and backwards, constantly surrounded by accumulated tears, absorb and carry them through the lachrymal canals, of which they are only the external orifices, into the lachrymal sac.

The absorption of the tears, and their transmission into the membranous reservoir in the cavity of the os unguis, does not depend on the capillary nature of the lachrymal canals, each of which, endued with a peculiar vital action, absorbs the tears accumulated in the *lacus lachrymalis*, and causes them to flow into the sac: the specific gravity of the liquid, and the pressure of succeeding columns, assist the action of the parietes of this canal; its passage is also facilitated by the compression and action of the orbicular muscles of the palpebræ, behind which these canals are situated. This vitality of the puncta and canals is particularly evident when we wish to introduce the tube of Anell's syringe, or Mejean's probe, to remedy cases of slight obstruction of the lachrymal passages. In a child now under my care for a mucous obstruction of the nasal duct, I can observe the punctum lachrymale contract when the extremity of the syringe does not pass directly down the canal; we are then obliged to wait for the cessation of this spasmodic affection, which only continues a few moments. The tears that flow into the lachrymal sac by the common orifice of the lachrymal canals united, never accumulate except in cases of obstruction; they pass directly into the nasal canal, which is merely a continuation of it, and fall into the nasal fossæ, where they mix with the nasal mucus, augment its quantity, render it more fluid, and alter its composition. The use of the tears is to defend the globe of the eye from the irritation that must have been produced by the mmediate contact of the atmosphere; they also facilitate the motion of the eyelids, obviate the friction of these parts on the eye, and thus conduce to its motions.

The Globe of the Eye.

LXXXV. This part, as already observed, may be considered as a dioptric machine placed before the retina, destined to refract luminous rays, collect them into a focus, which strikes one point of this nervous membrane, exclusively adapted to receive the impression. One external, membranous, firm, and consistent covering sustains all its parts. Next to this membrane, called sclerotic, is found the choroid, a black tunic that lines the interior surface of the sclerotic, and causes the eye to be a *camera obscura*. At the anterior part of the globe the sclerotic leaves a circular opening in which the transparent cornea is received; about the twelfth part of an inch distance from this convex segment in the anterior aperture of the sclerotic is found the iris, a membranous system, perforated by a round aperture (the pupil), which dilates or contracts conformably to the expansion or contraction of the iris.

At a very small distance behind the iris, about the union of the anterior quarter of the globe of the eye with the remaining three quarters, posterior and opposite the opening of the pupil, there is a lenticular body, inclosed in a membranous capsule, invariably fixed in the place it occupies by its adherence to the membrane of the vitreous humour.

Behind the crystalline lens the three posterior quarters of the cavity of the eye are filled with a viscous, transparent humour, inclosed in the cells of an extremely fine membrane, called hyaloid. This vitreous humour constitutes about two thirds of the sphere from which an anterior third might have been taken off: it is on the surface of this membrane and humour that the pulpy expansion of the optic nerve, called retina, is distributed, which adheres also as firmly to the choroid and sclerotic membranes.

The globe of the eye being almost spherical, this difference of its diameters is very inconsiderable; the diameter from the anterior to the posterior part, is ten or eleven lines: the transverse and vertical diameters are not quite so long. In the space formed by the antero-posterior diameter that forms the visual axis, are found, in passing from before, backwards, the cornea, the aqueous humour in the anterior chamber, the iris, and its central perforation, the aqueous humour of the posterior chamber, the crystalline lens, surrounded by the ciliary processes, then the vitreous humour inclosed in the hyaloid membrane; and behind these transparent parts of the eye, through which the luminous rays pass in approaching the perpendicular, are, the retina, that receives the impression, then the choroid, the black coat, pigmentum nigrum, which absorbs the rays that penetrate through the fine retina; and, lastly, the sclerotic, perforated for the entrance of the optic nerve into the globe of the eye.

The cornea inclosed in the anterior space of the sclerotic, like the glass of a watch in the frame of its outside case, is about the third of a line in thickness; it forms the segment of a smaller sphere before the eye, in addition to the anterior part of a larger sphere; behind it is the aqueous humour that fills what are called the chambers of the eye: these are distinguished into an anterior or larger space, limited by the cornea before and the iris behind; and into a posterior or smaller space, separating the crystalline lens from the iris, the posterior surface of which is covered with a black substance called *uvea*.

Some anatomists have doubted of the existence of the posterior chamber of the eye; but to convince themselves of the fact, it is only necessary to congeal it: a frozen liquid is then always found between the crystalline lens and uvea. This does not arise from the humour of the anterior chamber acquiring, like all other liquids, by congelation, a considerable power of expansion, and passing behind the iris through the aperture of the pupil; for the expansive power of fluids that congeal, being relative to their volume, the vitreous humour, which is also affected at the same time as the aqueous humour, should prevent its falling back on the pupil. Finally, the posterior surface of the iris, or uvea, is covered by a black substance that is easily detached; but if the anterior surface of the crystalline had come into immediate contact with it, a portion of its colour would have adhered and destroyed the natural transparency indispensable for the accomplishment of the mechanism of vision. It is therefore certain that the posterior chamber exists, being in proportion to the anterior chamber as two to five, and contains about two fifths of the aqueous humour, the whole quantity of which is estimated at five grains; and that the iris forms a floating septem between the two portions of the aqueous humour, with which the plaster on its posterior surface is immiscible. The aqueous humour seems to be the product of arterial exhalation: it is very speedily renewed, as seen in the operation for the cateract.

The specific gravity of the aqueous humour differs very little from that of distilled water; some have even considered it lighter; its nature is albuminous, and it contains some salts in solution. The crystalline lens inclosed in its membranous and transparent capsule, is a lenticular body more solid than liquid: its consistence is greatest towards the centre: its substance there forms a kind of nucleus, to which concentric laminæ are applied, the density of which diminishes in proportion as they approach the surface, where the most external of them being fluid, form what Morgagni believed to be a particular humour, on which the crystalline lens could receive nutriment by a kind of absorption. This body, composed of two unequal convex segments, about two lines thick in its centre, is formed by an albuminous matter, concrescible by alkohol and heat: very minute arteries, branching from the central artery, discovered by Zinn, through the body of the vitreous humour, supply it with fluid for its growth and nourishment.

The vitreous humour, which takes its name from the resemblance to melted glass, is less dense than the crystalline, but more than the aqueous humour; it is very considerable in the human eye, and seems to be formed by the small arteries that are distributed in the cells of the hyaloid membrane: it is heavier than common water, slightly albuminous and saline.

The sclerotic is a fibrous membrane, to which the tendons of the muscles that move the globe of the eye are attached; it supports all the parts of which this organ is composed, that collapse, and are destroyed whenever the continuity of its external covering is deficient. The choroid being finer, and principally vascular, serves less as a covering for other parts than as a black surface, destined to absorb the rays of light when they have produced a sufficient impression on the retina: if it did not exist, the light would be reflected after having touched the nervous membrane, its rays would cross each other, and only produce confused sensations. Mariotte had conjectured that the choroid was the immediate seat of vision, and that the retina was merely the epidermis of this membrane. This hypothesis would not have had the celebrity it obtained, if the example of fish had been objected to the doctrine, in which the choroid is separated from the retina by a glandular opake body, through which luminous rays cannot pass independent of analogous reasoning. The retina loses its form so soon as it is separated from the vitreous humour, or the choroid membrane, between which it is kept expanded like an extremely fine capsule, approaching fluidity. A great number of sanguiferous vessels, arising from Zinn's central artery, are distributed on the nervous substance of the retina, and occasion its light rose-colour. Is it to varicose or aneurismal dilatations of these minute vessels that we should attribute, agreeably to the sentiments of Boerhaave, the spots that are perceived on objects in that particular disease of the organ of vision, to which *Maitre Jean* has given the name of imaginations? To constitute the retina, the optic nerve that penetrates the globe of the eye, in perforating the sclerotic, to which the covering to this nerve from the dura mater unites, passes through a very fine membrane, which is perforated by an immense number of small holes; it closes this aperture, and belongs as much to the choroid as to the sclerotic; then extends to furnish the expansion that covers the concavity of the choroid membrane and convexity of the vitreous humour. The whole extent of the retina, equally nervous and sensible, can receive the impression of the rays of light, although some philosophers have only attributed this faculty to its central part, which they have called the optic axis. This central part is particularly remarkable in man for its yellow spot, discovered by Sœmmering: in the middle of this spot, that is, on the external part of the entrance of the optic nerve into the globe of the eye, there is found a dark point that is a superficial hole, the use of which is not yet known. This peculiarity of structure lately discovered is only observed in the eyes of man and the ape.

The Mechanism and Phenomena of Vision.

LXXXVI. Luminous rays emanating from a light object form a cone, the apex of which corresponds to the point of the body which we are looking at, and its base is applied to the anterior part of the cornea. All the rays that diverge too much, and fall out of the area of the cornea on the eyebrows, eyelids, and sclerotic, are lost to vision; those which touch the mirror of the eye pass through it, experience a refraction proportioned to the density of the cornea, and to the convexity of this membrane, greater than that of the atmosphere: when approaching the perpendicular they pass through the aqueous humour less dense, and meet with the iris. All those rays which fall on this membrane are reflected, and show its colour different in various individuals, and which seems to depend on the organic texture, the particular arrangement and diversity of nerves, vessels, and cellular texture that enter into the structure of the iris. It is only the most central rays that penetrate the pupil and serve for sight: these enter the pupil in greater or less number, according as it may be more or less dilated. The pupil becomes larger or smaller conformably to the expansion or contraction of the iris.

The motions of the iris depend entirely on the mode in which light affects the retina: it is of itself insensible to the impression of luminous rays, as proved by Fontana, who always found it immovable when he directed rays of light exclusively to it. When the retina is disagreeably affected by the brilliancy of a too strong light, the pupil contracts to admit of a small number of rays only to pass; it dilates, on the contrary, when we are in darkness, in order to admit a sufficient number of them to produce a proper impression on the retina.

To explain the motions of the iris, it is not absolutely necessary to admit that muscular fibres enter into its structure; it is sufficient to distinguish its vascular, spongy, and nervous texture: the irritation of the retina, sympathetically transmitted to the iris, determines a greater afflux of humours; its structure dilates, the circumference of the pupil is pushed towards the axis of this aperture, which is contracted by the expansion of the membranous texture. When the irritating cause ceases to act, and we retire from light to darkness, the fluids pass into vessels in the vicinity, the iris returns on itself, and the pupil enlarges in proportion to the excess of darkness.

The habitual dilatation of the pupil is a symptom of weakness, verminous affection, &c.

The rays to which the pupil gave passage pass through the aqueous humour of the posterior chamber, and soon come into contact with the crystalline lens, which powerfully refracts them on account of its density and lenticular form. When more approaching the perpendicular by this body they proceed as far as the retina through the vitreous humour, that is less dense, and which preserves without augmentation the effect of the refraction produced by the crystalline lens: the rays assembled into one focus strike only a single point of the retina, and produce an impression that gives us an idea of certain properties of the bodies it reflects. As the retina envelops the vitreous humour, it presents a very extensive surface to the contact of rays; for which reason we can see a great number of objects at once that are differently situated with respect to us, even when these objects or ourselves change their relative situation. Luminous rays, therefore, refracted by the transparent parts of the eye, form, on the internal part of this organ, a cone, the base of which corresponds to the cornea, and bears on that of the luminous external pyramid, while the apex is on any point of the retina. It is generally thought that luminous pyramids which emanate from all points of the object we behold, decussate in passing through the globe of the eye, so that the object itself is figured in a reversed situation. In admitting this conclusion to be established on a physical experiment, and some calculations that seem to me not infallible, we should investigate the reason why we see objects direct, notwithstanding their image is reversed on the retina. The best explanation of this phenomenon is by Berkely the philosopher, who proposed it in an English work, entitled, Theory of Vision, &c. According to him there is no necessity for touch to remove this error into which sight would lead us; as we connect all our sensations with ourselves, the rectitude of the object is only relative, and its inversion really exists in the bottom of the eye.

By the *distinct point of vision* is understood the distance at which we can read a book with characters of a moderate size, or distinguish any object of equal tenuity. This distance is not inclosed within very narrow limits, since we can read the same book whether it be within six inches of the eye, or six or seven times the distance. This faculty which the eyes possess, of accommodating themselves to the distance and smallness of objects, cannot depend, as considered by some, on the elongation or contraction of the globe of the eye by the action of the muscles that move it; its four recti muscles are in no instance capable of compressing its sides, of elongating it by altering the spherical form; their united action can only plunge the globe into the orbit, contract it from before, backwards, diminish its depth, and consequently render refraction less energetic when objects are very small or distant: this latter effect may be even doubted. The eye, which falls into a state of quiescence, and reposes on the adipose bed in the bottom of the orbit, is never so strongly compressed as to lose its spherical figure, which of all other forms is that which, by its particular nature, more powerfully resists changes. The extremities of the *ciliary processes*, which surround the circumference of the crystalline, cannot act on this transparent lentil, compress nor move it; for these small membranous plicæ; the assemblage of which composes the radiated disk, known by the name of *corpus ciliare*, not possessing any contractile power, are not capable of moving the crystalline, to which their extremities are merely contiguous and form no adhesion, and which is immovably fixed in the fossa it occupies by the cohesion of its capsule with the membrane of the vitreous humour. The different degrees of contraction and dilatation of which the pupil is susceptible, offer a much more satisfactory solution of this physiological problem.

The luminous rays that emanate from a very near object are extremely divergent: the eye would be deficient in refrangent powers necessary to assemble them into a focus, if the more divergent rays that form the circumference of the luminous pyramid were not separated by the contraction of the pupil and enlargement of the iris; then those which form the centre of the cone, and have only occasion for a small refraction to unite on a single point of the retina, are alone admitted by the contracted aperture. When, on the contrary, we look at a distant object from whence rays, already too convergent, emanate, and which only require a weak refraction to be made to approach the perpendicular, we dilate the pupil to admit more divergent rays, which, united, carry the image of the object. It is in this point of view that small bodies and others at a great distance are perceived.

Although the image of each object is traced at the same time in each of our eyes, we have but one sensation; because both sensations are in harmony or combined, and only serve, by assisting each other, to render the impression stronger and more durable. It has been long remarked, that sight is more precise and accurate when we make use of one eye only; and Jurine is of opinion that the power of both united is only equivalent to a thirteenth part more than the exercise of one eye only. The correspondence of affection requires the direction of the optic axes on the same objects; and however little this direction be changed, we really see double, which happens in strabismus, or squinting.

If the eyes possess a too energetic power of refraction, either from too great a convexity of the cornea or crystalline, more considerable density of the humours, and excessive depth of the globe of the eye, the luminous rays, being united too soon, cross each other, again diverge, fall scattered on the retina, and produce only a confused sensation. In this disease of vision, called *myopia*, patients can only distinguish very near objects, whence rays are given off, the great divergence of which requires an instrument possessing a considerable power of refraction. In *presbyopia*, on the contrary, the cornea being too flat, the crystalline not very convex, or too deep seated, the humours not sufficiently abundant, cause the rays not to be yet assembled, when they fall on the retina; so that patients can only observe with accuracy distant objects, because the rays that come from them being very convergent, have not occasion to be much refracted.

> Myopia is sometimes the effect of an habit that some children acquire by looking very closely at objects that fix their attention: the pupil then accustoms itself to a great contraction, and dilates afterwards with some difficulty. It must easily occur to the mind, that, to correct this vitiated disposition, objects should be presented to the infant that powerfully rouse the curiosity, keeping it at a considerable distance from every thing shown.

The sensibility of the retina is, under certain circumstances, so much raised, that the eye hardly supports the weakest light. Persons in this situation are called *nyctalopes*, who distinguish objects in the midst of utter darkness, as a few rays are sufficient to affect their organ of vision.

It is reported that an Englishman shut up in a dark place, gradually became able to distinguish every thing that was contained in it; when brought into the light, he could not support its brilliancy: the margins of the pupil, formerly very much dilated, contracted so as entirely to obliterate the aperture; on the contrary, when the retina possesses little sensibility, persons can only see in strong daylight. This affection of vision, called *emeralopia*, may be considered as the first degree of total paralysis of the optic nerve, or *gutta serena*, caused by any thing that will blunt the sensibility of the retina. St. Yves offers several observations on emeralopia, in his work on diseases of the eyes: they are concerning workmen employed in the mint, about casting the metal. The inhabitants of very northern countries, where the earth is covered with snow during the greater part of the year, soon become affected with this complaint: men, under both circumstances, contract this disposition, because their eyes are habitually fatigued by the lustre of too strong light.

In fact, for the mechanism of vision to take place, every part of the eye should be in a certain condition, the absence of which is more or less dangerous; it is more particularly important that the membranes and humours, through which the luminous rays must pass, should possess a most perfect transparency. Therefore, spots of the cornea; closing of the pupil by the *membrana pupillaris* remaining, that covers this aperture during the first months of existence in the fœtus; cataract, or an affection that consists in an opacity of the crystalline lens or its capsule; glaucoma, or a want of transparency in the vitreous humour; all these causes diminish or destroy the power of vision, by preventing the rays of light from reaching the retina: this membrane itself should possess a moderate degree of sensibility, to be properly influenced by their contact. The choroid membrane should have a surface sufficiently black to absorb the luminous rays. It is to the perceptible diminution of colour in the choroid as we advance in age, as well as to the induration and tint of different parts of the eye, and also the sensibility of the retina, blunted by long use, that we should attribute the difficulty and defect of vision in elderly persons. The extreme delicacy of the eyes of the *albinos* equally proves the necessity of the absorption of light by the black surface that covers the choroid.

The eyes have arrived at a greater degree of development in new-born infants than any other organ; they are then almost as large as they become during the remainder of life: thence it happens that the figures of children, the eyes of which are proportionably greater, are seldom disagreeable, because it is from this organ that physiognomy takes its principal characters. Might it not be said, that if nature has sooner completed the organ of sight, it is because the changes impressed on the rays of light being deduced from physical necessity, the perfection of the instrument was indispensable to the exercise of this sense?

The eyes are not immovable in the part they occupy, they are directed towards all the objects of which we wish to form a knowledge by different motions, regulated by four recti and two oblique muscles; and it is observed that there is such a correspondence of action in muscles that move both eyes, that these organs turn at the same time towards the object, so that the visual axes are exactly parallel. It sometimes happens that this harmony of motion is deranged, whence arises *strabismus*, an affection that mostly depends on the unequal power of the muscles of the eye; it may be distinguished into as many species, as there are muscles that can carry the globe of the eye in their own direction, when they happen to be possessed of a predominant power. Buffon has also ranged among the causes of strabismus, the different aptitude of the eyes to be affected by the light. According to this celebrated naturalist, it may happen that one of the eyes has more sensibility; infants, in which this difference exists, shut the weaker, and only use the stronger, which exercise continues to strengthen, while repose weakens the other that remains in a state of inaction.

The sense of sight seems, much more justly than that of smelling, to deserve the name that J. J. Rousseau gave the latter, *the sense of imagination*. As this brilliant faculty of the soul, the sight, that furnishes us with such rich and diversified ideas, is liable to lead us into many errors; we may doubt of the notions of distance it furnishes us with, since the blind-born person mentioned by Cheselden thought every object he perceived to be applied immediately to the eye: it makes us liable to false judgments on the shape and size of objects, since, agreeably to the laws of optics, a square tower seen at a great distance appears round, and very lofty trees, in a distant perspective, seem no larger than small bushes that are nearer to us; a body that moves with rapidity seems immovable, &c. It is by the organ of feeling that errors are corrected, which Condillac, in his treatise on *Sensations*, has, perhaps, too much exaggerated.

Consult this work, in other respects replete with excellent observations on the metaphysics of sensations, passions, and all actions, both moral and intellectual.

LXXXVII. The organ of sight, considered in the different animals that possess it, presents varieties that have a manifest relation to the media in which they exist: thus birds that soar in the upper regions of the air have a third remarkable eyelid, particularly the eagle, which enables it to face the sun; as have nocturnal birds, by which their very delicate eyes are defended from the too powerful impressions of a strong light: in those also the secretion of tears is very abundant, the parts they occupy being well adapted to assist evaporation. The generality of fish, on the contrary, have no movable eyelid; their eyes are not moistened by the lachrymal humour, the water in which they are constantly swimming seems to supply its place; yet the eyes of some of them are smeared with an unctuous substance, to moderate the friction of the liquid.

The globe of the eye in birds presents a very convex cornea, sometimes even absolutely semi-spherical; hence it possesses a strong power of refraction: this, however, in the eyes of fish is very weak, as the anterior part is flattened; but the water in which they live has the faculty of considerably breaking the luminous rays, by causing them to approach the perpendicular, and supplies the defect from flatness of the cornea, that arises from the small quantity of aqueous humour, which in some is entirely deficient.

The eyes of birds, of which the cornea is pushed forwards by a very copious aqueous humour, should, on the other hand, possess a very great power of refraction; since the air of the upper regions, on account of its extreme rarefaction, is not well adapted to approximate the rays of light.

The aperture of the pupil is more capable of dilatation in the cat, the owl, nocturnal birds, and in general all animals that can live in darkness. The sensibility of the retina appears also to be more active in this class of beings; some seem incommoded by the light of day, and only pursue their prey during complete darkness.

The crystalline humour of fish is spherical and not lenticular; this is the case likewise in several water-fowls, as the cormorant, &c. and it is not the only peculiarity of structure that is observed in this kind of amphibious animals, inhabiting, in rotation, both elements, as will be observed hereafter. Finally, the choroid membrane of certain quadrupeds is more easily separated into two distinct laminæ than in man, and presents at the bottom of the eye, instead of a blackish substance uniformly spread, a large spot, variously coloured, in some possessing the most beautiful brilliancy. It is difficult to assign any use to this coloured lamina, known by the name of *tapetum*.

The heads of insects that have numerous eyes, convey to the body all their motions; their existence is in other respects so weak, that nature could not too amply bestow on them the means of distinguishing prejudicial objects. We shall not proceed farther with these remarks, relative to the differences of the organs of sight in various species of animals: a more diffusive account of these things is in the province of comparative anatomy.

The Organ of Hearing. On Sound.

LXXXVIII. Sound is not, like light, a body existing by itself: we give this appellation to the sensation we perceive when the vibrations of an elastic body strike our ears. All bodies can produce it, provided their particles be susceptible of a certain degree of reaction and resistance. When a sonorous body is struck, its component particles suffer a sudden concussion, are displaced, and have a motion or oscillation more or less rapid. This internal tremulous action is propagated to bodies applied to its surface: if we place the hand on a bell, vibrating from the stroke of its clapper, a greater or less trembling is perceived; the air that envelops the sonorous body receives and transmits the vibrations with more advantage in proportion to its elasticity. Thus it is observed that, *cæteris paribus*, the voice is heard at a greater distance in winter, when the air is both more dry and condensed.

Rays of sound are only series of aerial particles, by which vibration is transmitted from the sonorous body to the ear, which perceives the noise resulting from percussion. These particles participate in the vibrations communicated to them; they change place and figure with greater facility the nearer they are to the body struck, and *vice versa*, for sound becomes more faint in proportion to the increase of distance.

The force of sound entirely depends on the extent of vibrations that the particles of a sonorous body suffer. In a large bell, struck with violence, the agitation of particles is such, that they are transmitted to a great distance, and the form of the body is visibly changed by it. Acute or grave sounds arise from a greater or less number of vibrations in a given time; but the vibrations will be so much the more frequent, as the sonorous body may have less diameter and extent. Two catgut strings of equal length, size, and screwed to the same pitch, make, in a given time, the same number of vibrations, and produce the same sound: this is called *unison*, in music. If we shorten either of the chords to half its extent, it will have as many more vibrations, produce a sound doubly acute, or is an octave higher; if we reduce its diameter to half, without diminishing its length, the same result is produced. The vibrations will be also accelerated by screwing up the sonorous chord. The diversity of sounds from a bass, harp, and in general all strong instruments, depends, on the inequality of their length, diameter, and tension.

Sound is propagated with much less celerity than light. The report of a cannon that is at a certain distance is not heard till an instant after the priming has been seen to blaze: its rays diverge, and are reflected at an angle equal to that of incidence when they meet an obstacle. The force of sound may be augmented as the brilliancy of light, by assembling and uniting its rays. Finally, sonorous rays that strike a hard elastic body, reflected by this body, do not less impress a vibratory motion, whence arises a secondary sound that augments the force of the first.

When these secondary sounds, produced by the percussion of a body more or less distant, reach the ear later than the primitive sound, they constitute the phenomenon called *echo*. Who is not acquainted with the ingenious allegory by which ancient mythology has expressed its nature, in making Echo the daughter of Air and Earth?

The Organ and Mechanism of Hearing.

LXXXIX. The organ of hearing in man is formed of three very distinct parts: one placed externally, serves to assemble and transmit sonorous rays, which are modified in passing through the intermediate cavity, situated between the external and internal ear. It is in the cavities of the third part of the organ, in the petrous portion of the temporal bone, that the nerve destined for the perception of sounds is situated. The *pavillon*, or concha of the ear, and external meatus auditorius, may be compared to a hearing trumpet, the expanded part of which, represented by the concha, collects the rays of sound that are transmitted by the tube formed by the meatus auditorius. The surface of the concha has several eminences, separated by depressions in proportion to the projections: the concave surface is not directed entirely outwards in those who have not flattened the ear by compression in dress; it is directed a little forwards, and this disposition, favourable to the collection of sounds, is particularly remarkable in savage nations, in which hearing is well known to be unusually acute. The base of the concha is formed by a fine, elastic, fibro-cartilaginous substance, convenient for reflecting sounds, and, by the vibrations of which it is susceptible to augment their force and intensity. A very delicate skin covers this cartilage, under which no adeps is deposited, as that would have diminished its elasticity; and small muscles are attached to its projections, which can relax, and thus render them convenient for the reception of acute or grave sounds. These small muscles are known by the name of proper, as the helix major and minor; but the tragus, antitragus, and transversus, are common muscles, stronger, and better marked in timid animals with long ears. In the hare, the fibres of these muscles are so strong, and their action so evident, that this weak, fearful animal, being only enabled to escape the dangers that continually surround its existence by flight, requiring to be early informed of their approach, can not only change them into various and convenient forms, but also move them in every direction, carry them towards the parts whence sounds are propagated, and collect the most imperfect.

The form of the concha of the ear in man is not sufficiently adapted, whatever may have been advanced on this subject by Boerhaave, for all the rays of sound that strike it, and are reflected in an angle equal to that of incidence, to be directed towards the meatus auditorius externus: when united chiefly into one focus, and directed towards the concha, they pass into the auditory canal, and the tremulous motion excited in its osseo-cartilaginous parietes contributes to increase their force: the rays of sound, thus conveyed, then strike the membrane of the tympanum, a fine, transparent membrane, expanded between the bottom of the auditory canal and the cavity in which are contained the four *ossicula auditûs*. These four small bones form a chain passing inwards to the drum of the ear, and extending from the membrane of the tympanum to that which unites the base of the *stapes* to the sides of the *fenestra ovalis*.

An elastic air, continually renewed by the tube of Eustachius, fills the cavity of the tympanum. Small muscles attached to the *malleus* and *stapes* move these bones, stretch or relax the membranes to which they are attached, and thus adapt the organ of hearing to the sounds which strike it. We may easily conceive that the relaxation of the membrane of the tympanum, effected by the action of the anterior muscle of the *malleus*, must diminish acute sounds, while the tension of this membrane by the internal muscle of the same bone can augment the force of grave sounds; in the same manner as the eye, by a contraction or dilatation of the pupil, accommodates itself to the light, and may admit a greater or less number of rays, according to the impression they produce. Thus, by the relaxation or tension of the membranes of the tympanum and fenestra ovalis, the ear diminishes or increases sounds, the violence of which would disagreeably excite its sensibility, or would not produce on it a sufficient impression. The iris and muscles of the malleus and stapes are, therefore, *moderatores* of auditory and visual impressions: sympathetic connexions are also as powerful between the auditory muscles and nerve, as between the iris and retina. The air which fills the cavity of the drum is the true vehicle of sound; this air is diffused in the cells of the mastoid bone, the uses of which are evidently to augment the capacity of the drum, as well as the force and extent of vibration that the air suffers in it.

The vibrations, transmitted by the membrane of the tympanum, are communicated to those which close the apertures of the fenestra ovalis and fenestra rotunda, and by the medium of these latter, to the aqueous humour that occupies the different cavities of the internal ear, in which the soft, delicate filaments of the auditory nerve, or the *portio mollis* of the seventh pair, float.

The undulations of the fluid affect these nerves, and produce the sensations of acute or grave sounds, according as they may be more or less rapid. It should appear that the diversity of sounds ought rather to be attributed to the degree of oscillatory motion, and force or weakness of undulation in the lymph of Cotunnus, than to the longer or shorter continuance of impression on the filaments of the auditory nerves. These nervous expansions are too soft and fine to be traced to their ultimate termination; yet it is probable that the varied forms of different parts of the internal ear *(the semicircular canals of the vestibulum and cochlea)* have some influence in the diversity of sounds. It should also be observed, that the cavities of the ear are formed in a bony substance, harder than any other structure of a similar nature, and proper to maintain, or even augment by reaction, the force of rays of sound.

The essential part of the organ of hearing, and which appears to be exclusively invested with the sensation of sounds, is doubtless, that which exists in all animals endued with the faculty of hearing: this is constituted by the *portio mollis* of the auditory nerve, floating in a gelatinous fluid that is contained in a fine, elastic, membranous sac. It is found in all animals from man down to the cuttle-fish, below which an organ of hearing has not been distinguished, although several beings lower in the scale of gradation seem not to be absolutely deprived of it. This gelatinous pulp, in which resides the organ of hearing in the crab, is first enveloped in a firm and horny lamina: in animals of higher class its internal part is divided into several bony cavities. In birds a cavity is interposed between that which incloses the auditory nerve and the external part of the head; finally, in man and quadrupeds the auditory apparatus becomes very complex; the organ of hearing is inclosed in a bony part, very hard, deep-seated, separated from the external part of the head by a cavity and a canal, through which sonorous rays pass, collected into a focus.

This kind of natural *analysis* of the organ of hearing is very necessary to give exact ideas of the nature and importance of the functions with which each of its parts is invested. But to arrive at this determination of the use and importance relative to each portion of the auditory apparatus, pathology offers examples as useful as comparative anatomy.

XC. The concha of the ear may be removed with impunity in man and even in animals, where its conformation is more advantageous: the ear in a few days acquires its accustomed delicacy. The entire obliteration of the meatus auditorius externus occasions complete deafness. The perfection of the membrane of the tympanum is not essential to the mechanism of hearing. Individuals in whom this was absolutely ruptured could not evacuate smoke by the ear without being deprived of the faculty of hearing. Although we may conceive a small opening that would not prevent it from receiving a percussion by the rays of sound, and obeying the influence of the handle of the malleus to contract or relax it, yet if the membrane of the tympanum were destroyed throughout the greater part of its extent, deafness would be almost inevitable. If the air filling the cavity of the tympanum be not renewed, in consequence of obstruction in the tube of Eustachius, its elasticity is lost, and it combines with the mucus that moistens the surface of the cavity of the tympanum. The same event then takes place in this cavity as in a bell, exhausted by the air-pump, through which vacuum sonorous rays pass with difficulty. It has been believed that the tube of Eustachius does not only serve to renew the air contained in the cavity of the tympanum, but also to give passage to rays of sound. When we listen with great attention the mouth is a little opened; that is, say they, for sound to pass from this cavity into the pharynx, and thence through the Eustachian tube into the organ of hearing. Without denying that rays of sound may be introduced, at the same time, by the Eustachian tube and meatus auditorius externus, we should contemplate a more evident utility in a depression of the inferior maxilla, that renders the mouth of every attentive auditor a little open. In this motion its condyles, placed anterior to the meatus auditorii externi, descend, and are carried forwards, and these canals are evidently dilated, which is easily proved by introducing the little finger into the ear at the instant this motion is performed. The luxation of the *ossicula auditus*, or even their complete destruction, does not cause deafness; the result is only a confusion in the perception of sounds. But the destruction of the stapes, the base of which forms the greater portion of the fenestra ovalis, should, as well as a laceration of the fine membrane that closes the fenestra rotunda, occasion deafness by the evacuation of the liquid that fills the cavities in which the auditory nerve is distributed.

The existence of this liquor seems essential to the mechanism of hearing, whether it keep the nerves in a state of softness and humidity necessary for sensation, or transmit the undulatory motions by which it is agitated.

The deafness of elderly people, that depends, according to authors, on the blunted sensibility of the auditory nerves, on account of the repeated impressions having exhausted their excitability, seems to be sometimes occasioned by a defect of this humour, and dryness of the internal cavities of the ear. During the severe winter of 1798, Professor Pinel, at the hospital Salpêtrière, caused the cranium of several women to be opened, who died at an advanced age, and had lost their hearing for several years. The cavities of the internal ear were found perfectly empty: they were filled with a cake of ice in younger persons who had possessed the faculty of hearing.

Deafness may be also produced by the paralysis of the *portio mollis* of the seventh pair of nerves, by an affection of that part of the brain whence they arise. It is impossible to explain, on principles of mechanism, as Willis has attempted, the different variations of structure in the organ of hearing, the affections in which it is moved by strong or weak sounds acting separately, or in conjunction.

On Odours.

XCI. The chemists have long believed that the odorous part of bodies formed a peculiar principle, distinct from every other substance that enters their composition. It has been known by the name of *aroma;* but Fourcroy has clearly demonstrated that this pretended element consists only in attenuated particles of bodies, detached by caloric and dissolved in the air which carries them to the olfactory surface. Agreeably to this theory, all bodies are odorous, since the matter of heat can sublime some particles, even of those that have the greatest degree of fixity. Linnæus and Lorry endeavoured to class odours according to the sensations they produced.

> Linnæus admits seven classes of odours: 1st class, *Ambrosiac;* the rose and musk are of this number: their character is tenacity. 2d, *Fragrant;* as the lily, saffron, jasmin: they easily dissipate. 3d. *Aromatic;* as the laurel. 4th, *Alliaceous;* bearing a greater or less relation to the exhalation of garlic. 5th, *Fetid;* as valerian and mushrooms. 6th, *Virous;* as poppies, opium. 7th, *Nauseous;* as gourd, melon, cucumber, and in general all the cucurbitacei.
>
> Lorry only admitted five classes of odours: camphorated, narcotic, ethereal, acidulous volatile, and alkaline.
>
> Fourcroy calls that aroma of plants *mucous*, which was formerly termed inodorous, oleaginous and fugitive, oleaginous and volatile, acid and hydro-sulphureous.

Fourcroy has adopted for the basis of this inquiry the chemical nature of bodies; but whatever advantage this latter method may possess, it is difficult to comprehend the odours varied *ad infinitum*, that exhale from substances of the three kingdoms; and it is, perhaps, as impossible to class them as the bodies from which they exhale.

Having premised this on the nature of odours, it is evident why the atmosphere receives them more easily, in proportion to its warmth and humidity. It is a known fact, that in a flower-garden the air is at no time more abundant of sweet perfumes, nor the organ of smell productive of more delightful sensations than in the morning, when the dew evaporates, and is dissipated by the rays of the rising sun.

The Organs of Smell.

XCII. The nasal fossæ, in which this organ resides, are two great cavities on the face, and are continued farther by posterior cavities formed in the substance of the coronal, ethmoid, sphenoid, palatine, and maxillary bones. A thick, mucous membrane, always moist, in the structure of which are distributed the olfactory nerves, as well as a great number of other nerves and vessels, line its interior surface, are continued into the sinuses connected with it, and cover their projections and depressions. This soft, spongy membrane, called pituitary, is the secretory organ of nasal mucus; it is thicker at the surface of the windings on the internal part of the olfactory cavities, it becomes thinner and firmer when deeper seated in the different sinuses.

The smell seems to be more delicate when the nasal fossæ have more extent, and the pituitary membrane offers a surface of greater extent: the habitual state of moisture and softness of this membrane is also a condition necessary to the perfection of this sense. In the dog, and all animals that excel in acuteness of smell, the frontal, ethmoid, splenoid, palatine, and maxillary sinuses, have a surprising extent, and the parietes of the cranium are in a great measure excavated by the appendages of the olfactory apparatus: in them also the projections are considerable, and the sinuses that separate them very deep; finally, the nerves of the first pair are proportionally large.

> Among animals that excel in acuteness of smell, there is none more remarkable than the hog. This filthy quadruped, accustomed to exist in the midst of the most infectious and unpleasant odours, has, notwithstanding, such a subtile smell, that it can detect certain roots buried in the earth a considerable distance. In several countries, this quality is rendered useful in finding truffles. The animal is led to the place where they are suspected to be, soon burrows into the earth in which they are concealed, and would devour them with avidity if the grazier were not to drive it away, and reserve the food for more delicate palates.

Sensations of Odours.

XCIII. Do the nerves of the first cerebral pair only invest the pituitary membrane with the property of receiving the impression of odours, and the numerous twigs arising from the fifth pair merely for the purpose of general sensibility? This question, in my opinion, should be answered in the affirmative. The pituitary membrane, in fact, possesses two different and very distinct modes of sensibility, since one of them may be entirely obliterated, while the other is considerably augmented. It is thus in a violent coryza that the ordinary sensibility is very acute, since the pituitary membrane is painful; the person at the same time is not conscious of the strongest odours.

It appears probable that the olfactory nerves do not extend into the sinuses, and that these posterior cavities only increase the perfection of smelling by longer retaining a greater mass of air loaded with odorous particles. The true seat of this sense is the superior part of the nasal fossæ, which the nose covers like the chapiter of a pillar. There the pituitary membrane is more moist, and receives into its texture the numerous ramifications of the first pair of nerves, which, arising by two roots from the anterior lobe of the cerebrum, and the depression that separates it from the posterior lobe, passes out of the cranium by the orifices of the cribriform lamella of the ethmoid bone; and terminates in forming, by an expansion of its filaments, a kind of parenchymatous structure, difficult to be distinguished from the texture of the membrane. The olfactory papillæ would be soon dried by the continual contact of the atmospheric air, if they were not covered by the nasal mucus: the use of this humour is not only to preserve the sensibility of nervous extremities, by obviating dryness, but likewise to moderate the too strong impression that would arise from the immediate application of odorous particles; perhaps it may even combine with odours, and the latter only affect the olfactory nerves when dissolved by mucus, in the same manner as savoury food affects the nerves of the tongue through the medium of the saliva.

Since air is the vehicle of odours, they do not touch the pituitary membrane until we attract them by inspiration into the nasal cavities; therefore, when any odour is agreeable, we make short and frequent inspirations, and at the same time shut the mouth, that the air which enters the lungs may pass entirely through the nasal fossæ; on the contrary, we breathe by the mouth, or suddenly suppress respiration when odours are unpleasant to us.

The smell, like all other senses, is very susceptible of impression in children, although in them the nasal cavities be very narrow, and sinuses have no existence. The general exaltation of sensibility at this time of life supplies the defect arising from an imperfection of organization; and in this respect the nasal fossæ are like the auditory structure, a part of which, equally important (meatus auditorius externus), is not yet completely developed. The smell becomes more perfect by the loss of some other sense. Every one knows the history of the blind man, that could inform himself of the prudence of his daughter by this organ. It is blunted by the use of strong and penetrating odours: it is on this principle that snuff alters the mucous secretion of the membrane lining the nasal fossæ, changes its structure, dries the nerves, and ultimately destroys their sensibility.

The small distance between the origin of the olfactory nerves in the brain, and their termination in the nasal fossæ, renders the transmission of impressions they experience very sudden and easy. This proximity of the brain induces us to apply to these nerves stimuli that are proper to revive sensibility when life is suspended, as in cases of weakness and suffocation, or asphyxia.

On Tastes.

XCIV. These are neither less various nor numerous than odours; it is also equally difficult to reduce them to general classes that have analogy and comprehend the whole: however, there does not exist any other savoury element than the odorous principle.

> This is what Boerhaave, Haller, and Linnæus have attempted with so little success. *Acid*, *sweet*, *bitter*, *acrid*, *saline*, *alkaline*, *vinous*, *spirituous*, *aromatic*, and *astringent*, are the names by which these physicians have described general characters of tastes.

The taste of fruit changes with their maturity, and seems rather to be dependent on the intimate composition of bodies, and their peculiar nature, than the form of their moleculæ; since crystals of the same form, but from different salts, do not produce similar sensations.

For any body to affect the organ of taste, it should be soluble at the ordinary temperature of the saliva. Every insoluble body is insipid, and the axiom of chemistry, *corpora non agunt nisi soluta*, may be well applied to the organ of taste. If there be an absolute deficiency of saliva, and the body masticated totally void of humidity, it will only affect the dried tongue by its property of touching, and not in the least by its savour. The tongue is covered by a mucous, whitish, yellow, or bilious slime; we have only a false idea of savours; the covering more or less thick prevents the immediate contact of sapid particles; besides, when they act on the nervous papillæ, the impression they produce is confounded with that caused by a foul stomach; therefore all aliment seems bitter when a bilious disposition exists, insipid when there is a superabundance of mucus, &c.

The Sense of Taste.

XCV. No sense approaches nearer to feeling, nor has greater resemblance to it. The gustative surface only differs from the common integuments, in the skin, rete mucosum, and cuticle that envelop the muscular substance of the tongue being softer, less thick, and receiving a greater quantity of vessels and nerves; it is also habitually moistened by saliva and mucus, secreted by glands situated in its substance. These mucous cryptæ, and the nerves that are distributed on the cutaneous covering of the tongue, elevate the very fine cuticle or epidermis that is expanded over its anterior surface, and form a great number of papillæ, distinguished by their figure into fungous, conical, and villous. These small eminences, except those of the first species, are formed by the extremities of nerves that surround a lace-work of sanguiferous vessels: it is on account of these vessels that the papillæ possess the power of swelling, becoming elevated, and experience a kind of erection when we masticate high-flavoured food, or have a strong desire for any savoury dish.

The superior surface of the tongue is the seat of taste; yet it cannot be denied but that the lips, gums, the membrane that covers the arch of the *ossa palati*, and the *velum pendulum palati*, can be affected by the impression of some tastes.

> Principally on the anterior part of the membrane of the palate. The naso-palatine nerve, discovered by Scarpa, after being detached from the ganglion of Mekel, and passed through a long course into the nasal fossæ, terminates in that thick rugous part of the palatine membrane, situated behind the upper incisor teeth, and frequently touched with the apex of the tongue.

It is observed that the organ of taste in different animals is more perfect in proportion as the nerves of the tongue are larger, the skin finer and more moist, its texture flexible, surface extensive, motions more easy and varied. Thus the os hyoides of birds, in diminishing its flexibility; the osseous scales on the tongue of a swan, by diminishing the extent of its sensible surface; the adhesion of the tongue to the maxilla of the frog, salamander, and crocodile, by impeding the facility of its motions, render the sense of taste in these animals more obtuse, and less proper to perceive the impression of sapid bodies than in man and others of the *mammiferous* class. The sense of taste in man would be, perhaps, more delicate than that of any other animal, if he were not to blunt its sensibility early in life by strong drinks, spicy ragouts, and all the refinements of luxury that are daily invented. Quadrupeds, the tongue of which is covered by a rougher skin, distinguish poisonous or deleterious substances by taste better than we; and it is a known fact, that among the various vegetables that cover the surface of the earth, every herbivorous animal selects a certain number of plants more analogous to its nature, and constantly rejects those which are otherwise.

XCVI. Is the lingual branch of the fifth pair of nerves alone adapted for the perception of taste? Do not the ninth pair that are almost entirely distributed in the structure of the tongue, and the glosso-pharyngeus of the eighth, equally serve for the same purpose? The greater number of anatomists, since Galen, believed that the nerves of the eighth and ninth pair supplied the tongue with nerves of motion, while the fifth were for sensation; yet we can trace some filaments of the great hypoglossus as far as the nervous papillæ of the tongue. This nerve is larger than the lingual, and more exclusively distributed on this organ than the fifth pair from which the other nerve arises. Hevermann says he saw taste destroyed from the ninth pair having been divided in the extirpation of a scirrhous gland. His observation, adopted without examination, appears to me very doubtful: the lingual, in such a case, would still perceive tastes, although their impression would be weakened. A section of the great hypoglossus could only render that half of the tongue insensible on which it was distributed; the other half continues to possess its usual sensibility.

The tongue, although apparently a single organ, is formed of two parts that bear an exact symmetry; and four muscles are found on each side: stylo-glossus, hyo-glossus, genio-glossus, and lingualis; three nerves, lingualis, glosso-pharyngeus, and hypoglossus magnus; one artery, and one vein, the ranine; and a fasciculus of lymphatic vessels exactly alike. All these parts, by their union, form a fleshy body of a dense texture, difficult to distinguish, similar to that of the ventricles of the heart, endued with great mobility from the vessels and nerves distributed in its substance. If we compare their number and magnitude with the smallness of the organ, it will be found that if no part of the body perform more frequent, extensive, and varied motions, no individual part receives more vessels and nerves. A middle line separates and marks the limits of each half of the tongue, which, anatomically and physiologically considered, seems to be composed of two distinct organs, closely applied to each other.

Pathological phenomena confirm this independence of both parts of the tongue; in *hemiplegia*, that which corresponds to the paralytic part of the body also loses its power of motion; the other preserves its faculty, and draws the tongue towards that side. In cancer of the tongue, one of the sides often remains free from the affection that is destroying the opposite portion: in fact, the arteries and nerves of the left, seldom anastomose with those of the right side; an injection thrown into one of the ranine arteries only fills the corresponding half of the organ.

On Touch.

XCVII. There is no part of the surface of our body that is not exposed to receive the contact of an extraneous substance without our being soon informed of it. In fact, if the organs of sight, hearing, smell, and taste, only occupy circumscribed spaces, the touch resides in all other, and effectually watches over our preservation. The touch, distributed on the whole surface, seems to be the elementary sense, and all the other senses only modifications, accommodated to certain properties of bodies. Every thing that is not *light*, *sound*, *odour*, or *savour*, is appreciated by the touch, which thus informs us of the generality of the qualities of objects that it is necessary for us to know, as their temperature, consistence, state of dryness or moisture, form, magnitude, distance, &c.; it corrects the errors of sight and other senses, of which it may be justly called the regulator. This, above all others, furnishes us with the most certain and exact ideas.

The general covering of the body is the principal organ of this sense, which resides in the dermis or skin; the cellular texture that unites all these parts forms round the body a more or less thick mass, covering all its parts (panniculum adiposum); in proportion as they approach the surface its laminæ approximate, are more closely connected, and no longer separated by adeps. It is by this more intimate juxta-position of the laminæ of this texture that the cutis is formed, a thick elastic membrane, in the substance of which are distributed many vessels of every kind, and to which are carried such abundance of nerves, that the ancients did not hesitate to consider the skin entirely of nervous texture. The chemical analysis of cutaneous structure proves that it does not perfectly resemble cellular and membranous parts; it is gelatino-fibrous, and keeps the medium as well by its composition as its share of contractility between cellular membrane and muscle: a great number of small mammillary, fungous, conical, pointed, obtuse, and variously formed papillæ arise from the surface of the skin in different parts of the body. These projections are only the pulpy extremities of nerves, surrounded by a vascular net-work of surprising tenuity, more conspicuous on the lips and fingers than in any other part: the papillæ swell when irritated, elevate the cuticle; and this kind of erection is useful when we wish to examine a body with care, and may be excited by friction, moderate heat, &c.

The nervous or sensible surface of the skin is covered with a mucus, destitute of colour in Europeans, but rendered dark, or even black, by the light in the inhabitants of southern and hot climates: it is of a gelatinous nature, destined to keep the nervous papillæ in a state of softness and humidity, which assists the phenomena of feeling. It is in this mucilaginous substance, known by the name of *rete mucosum of Malpighi*, that the principle of colour seems to reside, which is so much diversified in the skin of different people, as will be explained under the article of the varieties of the human species.

The skin could not perform its functions were it not prevented from becoming dry by a fine, transparent membrane, called epidermis. This superficial covering is perfectly insensible; neither nerves nor any kind of vessels are found in it; and the manner in which it is formed, restored, and reproduced when destroyed, is still a problem undetermined in the present state of science: the most minute researches into its structure only show a great number of laminæ, lying on each other like tiles, on the roof a house. This imbrication of cuticular laminæ is very obvious in fishes and reptiles, the scaly skin of which is only epidermis or cuticle, the parts of which are formed in a larger proportion.

Haller believed that the cuticle is produced by a desiccation of the most external part of the rete mucosum; Malpighi was of opinion that it was the result of an hardness of the skin from the great pressure of the atmosphere on the surface of the body. Agreeably to these hypotheses, why is the embryo that swims in the liquor of the amnion furnished with this covering from the third month of its existence? Pressure renders it hard and callous, and greatly increases its thickness, as may be seen in the palms of the hands and soles of the feet in persons accustomed to laborious employment. The epidermis or cuticle is reproduced with surprising facility; when detached in scales after an erysipelas and cutaneous eruptions, or removed from a large surface by the action of blisters, it is regenerated in a very few days: this covering, with the nails and hair, which may be considered as its productions, are the only parts in man capable of regenerating themselves. The hair and horns of quadrupeds, the feathers of birds, the calcareous shell of the lobster, and others of that species, the shell of the tortoise, and solid coverings of a great number of insects, &c. possess this singular property like the epidermis. In other respects the chemical nature and structure of these bodies are the same; all contain a considerable proportion of phosphat of lime, greatly resist every attempt in decomposition, and afford a large quantity of carbonat of ammoniac by calcination. The use of the epidermis is to cover the nervous papillæ, in which the sense of touch principally resides, to moderate the impression that would be too sensible from an absolute contact of substances, and to prevent the air from rendering the skin dry, and blunting its sensibility.

XCVIII. The faculty of forming a knowledge of tangible qualities is invested in every part of the cutaneous organ; it is only necessary to apply a substance to any part of the surface of the body to acquire an idea of its temperature, dryness, humidity, weight, consistence, and even particular form: but no part is better adapted to furnish us with exact notions on all these properties than the hand, which has been at all times considered the principal organ of touch. The great number of bones that enter into its structure renders it susceptible of infinite variety of motions, by the assistance of which it changes its form, is accommodated to the inequality of surface of different objects, and covers them with exactness: this advantageous conformation is particularly evident at the extremities of the fingers; their anterior part, which possesses the most delicate sensibility, receives large ramifications from the median and cubital nerves, which terminate by forming round, compact tufts, surrounded with cellular texture. This part of the fingers, called their pulp, is supported by the nails; numerous vessels are distributed on this nervous-cellular structure, and moisten it with a humour that preserves its flexibility: when perspiration is copious, it is seen exuding in drops from the concentric depressions of the cuticle in this part.

> The nails are only a part of the epidermis more dense and hard, equally inorganic, squamous, rapidly growing from their root towards the loose margin, reproduced with facility: their use is to support the soft pulp of the fingers, when applied to a body that offers resistance.

Some physiologists have endeavoured to account for the pleasure we experience in feeling rounded surfaces without any roughness, by observing that the reciprocal formation of the hand, and of the body to which it was applied, was such as to bring them into contact in the greatest possible number of points. The delicacy of the touch is maintained by the fineness of the epidermis; it is increased by education, which has greater influence on this than on any other sense. It is well known with what avidity the child, permitted the free use of his members, carries his little hands over all the objects within reach, and what pleasure he seems to take in touching all their parts and surfaces. Blind persons have possessed the sense of feeling to such an eminent degree, as even to distinguish the variety of colours and their different shades. As the difference of colouring is influenced by the disposition, arrangement, and number of small inequalities that exist on the surface of bodies which seem the most smooth, and render them capable of reflecting one or another ray of light, and of absorbing all the rest, we do not refuse giving confidence to facts of this nature, reported by Boyle and other philosophers.

Some parts seem endued with a peculiar sense of touch, as the lips, the texture of which swells and expands by a voluptuous contact, a vital turgescence that is explicable without admitting a spongeous substance in their structure: such organs Buffon considered to be the seat of a sixth sense.

> In the generality of animals destitute of shells, feathers, or hair, the lips, particularly the inferior, are always the organ of an imperfect touch: the fleshy appendices of certain birds and several fish, situated in the vicinity of the aperture of the mouth, are destined for the same intention. The tail of the castor, antennæ of the butterfly, and the trunk of the elephant, are also parts of their body, in which the sense of touch exists in the greatest delicacy.

XCIX. Feeling, of all other senses, is more generally spread through the whole genera of animals; all possess it, from man, who, by the perfection of this sense, is above all other animals with vertebræ, down to the polypus, that is reduced to touch only, which it has in such an eminent degree, that, to use an appropriate expression of *Dumeril*, it perceives even light. The skin of man is finer and more nervous than that of other mammiferi; its surface is only covered by the epidermis (a part absolutely insensible), but so fine that it does not intercept sensation, while the hair with which it abounds in the bodies of quadrupeds and the feathers of birds, greatly diminish its energy. The hand of man, that admirable instrument, the structure of which, according to some philosophers, sufficiently points out the superiority he possesses over every other species of living creatures; the hand of man, naked and divided into a great number of movable parts, susceptible of changing its form every instant, of closely surrounding the surface of bodies, is better adapted to appreciate their tactile qualities than the feet of the quadruped, covered with an horny substance, and the foot of a bird, invested with scales too thick not to have considerable influence in blunting sensation. (See Galen, *De Usu Partium*, cap. iv. v. vi. Buffon, *Histoire Naturelle*, tom iv. v. in 12mo, &c.)

On Nerves.

c. These white chords that arise from the basis of the cerebrum, medulla oblongata, and medulla spinalis, are distributed over all parts of the body, and bestow on it both the power of perceiving and of moving. In this analysis of the functions of the nervous system, the natural order requires that we should consider them here as conductors of sensation; we shall afterwards see the manner in which they transmit the principle of motion to the organs that perform it. The nerves arise from all sensible parts by extremities, in general soft and pulpy, but of a consistence and form that are not alike in all; and it is to these varieties of disposition and structure that the modifications of sensibility in different organs should be attributed.

It may be said that there exists in the organs of sense a certain relation between the softness of the nervous extremity and the nature of bodies that make an impression on it. It is on this principle that the state of the retina approaching fluidity bears an evident proportion with the infinite subtility of light: the touch exerted by this fluid could not produce a sufficient impression unless the part perceiving it were susceptible of being affected by the smallest contact. The portio mollis of the seventh pair, destitute of any dense coat and reduced to a medullary pulp, easily participates in the sonorous vibrations transmitted by the fluid in which its filaments are floating; the nerves of smell and of taste are less covered, and present themselves more bare than the nervous papillæ of the skin, designed to receive impressions produced by the more obvious properties of bodies, &c.

Nerves are directed from their origin towards the brain, medulla oblongata, or spinal marrow, almost in a right line, seldom tortuous like the generality of vessels. When arrived at these parts they are lost in their substance, as will be mentioned after having investigated the structure of these nervous chords.

CI. Each nerve is formed of a great number of filaments extremely fine, every one of which has two extremities, one in the brain, the other at the part from which they arise, or in which they terminate. Each of these nervous fibres, whatever be its tenuity, is composed of a membranous coat that arises from the pia mater; a number of vessels of extreme fineness ramify on the parietes of this coat: its internal part is filled with a whitish pulp, which *Reil* affirms he took from the small canal that contained it, by concreting it with nitric acid; this dissolved the membranous covering, and left entire the medullary pulp that constitutes the essential part, or base of the nervous filament. The same physiologist has, by another method, detected the internal structure of each fibrilla of nerve; he dissolved the white or pultaceous part by long immersion in a lixivium, and thus succeeded in separating it from the membranous coat, which remained empty. The membranous covering, of a cellular nature, has nothing remarkable but its consistence, and the vast number of vessels of every kind distributed in the substance of its parietes; the nerve is left at its two extremities, and only covered in its passage.

Each nervous fibre, thus formed of two very distinct parts, unites to other fibres of exactly similar structure to form a nervous twig, which is covered by a common membrane from the cellular structure. These filaments assembled form ramifications, from which branches are composed, and by an assemblage of these a trunk is formed that is surrounded by cellular membrane; then other coverings for each fasciculus of nerves, and ultimately a peculiar covering to each filament. When these nervous chords are of certain dimensions, arteries and veins are seen of considerable size between the packets and fibres, dividing after passing into their substance, and furnishing capillary ramifications spread in the parietes of the covering of each filament: these are the small vessels, which, according to Reil, exhale the nervous substance into the interior of each membranous tube, that thus becomes the secretory organ of the *medulla* contained in it.

CII. These nervous filaments unite or separate without being in a confused mass. The division of nerves does not resemble that of arteries; their union cannot be compared to that of veins: it is, in the first case, merely a simple separation; in the second, only an approximation of filaments that had passed separately, and which, to be connected under a common membrane, do not the less preserve their own peculiar covering: it is only juxta-position, and they remain perfectly distinct. If that were not the case, it could not be said that each fibre has one of its terminations in the brain, and the other in any point of the body; nor could we conceive how the impressions that several sensitive extremities receive at once, should be propagated to the brain without confusion; nor in what manner the principle of motion could be directed towards a single muscle, which receives its nerves from the same trunk as other muscles of the member.

In general, nerves separate or unite under an angle more or less acute, equally favourable to the course of a fluid from the circumference to the centre, and from the centre to the circumference.

The structure of nerves is modified in certain portions of their system: thus the medullary fibres of the optic nerve are destitute of membranous coverings, as the pia mater forms only a single coat to the trunk formed by their assemblage; the dura mater adds a second coat at the passage out of the cranium. This covering, which is common to all nerves, leaves it at the entrance of the globe of the eye, and is united with the sclerotic coat. A small artery passes in the centre of the optic nerve, and afterwards dividing, forms a surprising net-work that supports the medullary pulp of the retina. The chords that pass through bony canals, as the nerve of the fifth pair, are destitute of cellular covering, and their consistence is always less firm than in nerves surrounded by soft parts.

CIII. Each nervous filament when arrived at the brain, the medulla oblongata, or medulla spinalis, as before mentioned, is deprived of its membranous covering that unites with the pia mater the immediate covering of these central parts of the sensitive system. The medullary, or white part, is continued into their substance, which may be considered as principally formed by the assemblage of these nervous extremities, which it is difficult to distinguish in its texture on account of its tender consistence. It has been long known that the origin of nerves is not at the point where they are detached from the brain; that they are plunged in its substance; that their fibres cross each other, so that those of the right side pass to the left, and *vice versa.* Sœmmering has traced the roots of nerves, and particularly those of smell, sight, hearing, and taste, as far as the eminences in the parietes of the ventricles of the brain, and believes that their ultimate extremity is moistened by the serosity on the contiguity of the internal surfaces. It may be conjectured with a degree of probability, that the cerebral extremities of nerves all unite in one determined point in the cerebral organ; and to this central point, which seems to be the annular protuberance of the medulla oblongata, all sensations are carried, while all determinations are given from it, whence arise voluntary motion.

The spinal marrow and nerves, in animals that possess them, are larger, compared with the size of the brain, in proportion to their distant gradation from the human species. In carnivorous animals the vast muscular masses required nerves of motion to be of a proportional magnitude: thus in them the brain is very small in comparison of the spinal nerves. It is observed that the same relation exists in certain men of an athletic temperament: all the nervous power seems to be employed in moving these large masses; and the nerves, although very small in proportion to the rest of the body, are large when compared with the cerebral organ. In children, women, and persons possessed of great sensibility, the nerves are very large; they shrink and become dry, in some measure, in aged persons: the cellular structure that surrounds them acquires a firmer consistence, forms a closer adhesion; and there exists a certain analogy between the nerves of old persons covered by this yellowish structure, which renders their dissection extremely tedious, and the branches of an old tree covered by a destructive moss.

As the uses of nerves cannot be treated on separately from those of the brain, we shall immediately pass to the history of this important viscus.

On the Coverings of the Brain.

CIV. If it be true that we should appreciate the importance of an organ by the care which nature has taken to protect it from external injury, none will appear more essential than the brain, for there is no one that seems to have been the object of a more attentive foresight. The substance of this viscus has so little consistence, that the least injury would have altered its structure and deranged its action; therefore it is found powerfully sheltered by several coverings, the most solid of which is, doubtless, the bony cavity in which it is inclosed.

Nothing seems better known than the numerous bones, the regular assemblage of which forms the different parts of the human head. Every thing that relates to the place they occupy, their respective magnitude, eminences and depressions, sinuses, every thing that regards their internal structure, the different proportion of substances of which they are composed, the aggregation of some of these substances in certain points of their extent, has been described by some modern anatomists with an exactness that it would be difficult to surpass. Yet several have not appreciated the direct influence of their mode of union over the use they are destined to fulfil; no person has sufficiently impressed the manner in which they all concur for one principal end, the preservation of organs inclosed in the cavities of the cranium and face.

Hunauld, in a memoir inserted among those of the Academy of Sciences, for the year 1730, was the first that endeavoured to account for the disposition of surfaces, by which the bones of the cranium are articulated. After having recapitulated some ideas relative to the theory of arches, and established that the difference of extent between their convex and concave surfaces required the oblique direction of pieces of which they are formed, he explains the utility of the squamous articulation between the temporal and parietal bones.

When the arch of the cranium is pressed with a too heavy weight they first prevent the parietal bones to which the force is immediately propagated from being pressed inwards or outwards. Hunauld justly compares them to supporters, that bear the same relation to the parietals as the upright walls to the arch they support.

Bordeu endeavoured to establish for the bones of the face what Hunauld had done for those of the cranium (*Académie des Sciences*, *Mémoires présentés par les Savans Etrangers*, tom iii.). According to him, the greater part of the bones of the face, particularly the superior maxillæ, resist the power of the inferior maxilla, which, by acting on the superior dental arch, continually tends to push upwards or outwards the bones in which the teeth are fixed: as the most considerable part of the effort is upwards, so on this part the bones of the maxilla superior are more firmly supported on those of the cranium. The author concludes this memoir, filled with ingenious observations, by proposing to physiologists the solution of the following problem: *When a man supports a great weight on the head*, *and presses something firmly between the teeth*, *which bone of the head makes the greatest exertion? which is the one that supports the whole machine?*

The body of the sphenoid bone, and particularly its posterior half, seems to be the central point in which unite the efforts of the cranium and bones of the face in the circumstance proposed by Bordeu. In the third volume of Memoirs of the Medical Society may be seen the collection of proofs adduced in support of this opinion.

The name that the ancients have given to the bone, the chief use of which I have elucidated (compounded of *sphenos*, that signifies a wedge, and the particle *eidos*, which carries the idea of similitude), should induce us to believe that they were not acquainted with its use. Situated in the smaller and inferior part of the cranium, having a more or less extensive connexion with all the bones that concur in the formation of this osseous covering, it performs the same function with respect to them as the key-stone of arches bears to the different component parts. The numerous relative connexions required for this purpose account for its irregular and extraordinary form, the different direction of its articular surfaces, the number of eminences by which it is surrounded, and render its demonstration so complicated, and the knowledge of it so difficult.

It is of more considerable utility with regard to the brain that the cranium is composed of several bones than if it were in one only; it offers a greater resistance against blows, because their effect is weakened by being transmitted from one bone to another, and lost in the small degree of motion that can take place between their sutures; its round form also increases the power of resistance. This force or power would be equal in all the points of the parietes of the cranium, if the figure of this part were exactly spherical, and the thickness of its parietes equal. Fractures by *contre-coup* could not then happen, a kind of injury which shows the unequal resistance opposed by the bones of the head to the powers applied to their surface. The pericranium, the scalp and its muscles, the hair covering it, also serve to protect the mass of brain, and are well adapted to lessen the violence of blows on the cranium.

The hair, without doubt, must be of still greater importance: its bulbous root, cuticular nature, the facility of reproduction even after the complete evulsion of the bulb, as frequently seen after the cure of *tinea*, by a method, the barbarity of which has been exaggerated; we also know its peculiar property with respect to the electric fluid, of which it is a bad conductor, a remarkable property with regard to the conjectured nature of the nervous fluid. The following observation seems to prove that it may be the excretory organ of some principle, the retention of which might be productive of serious consequences: a Carthusian, who had his head shaved every month, conformably to a rule of his order, after its dissolution went into the army, and permitted his hair to grow. Several months afterwards he was tormented with intolerable pains in the head, which resisted the effect of every remedy. He was, at last, advised to have recourse to his former custom, of having the head shaved at certain periods: the pains left him, and he had no return of them.

Besides this hard and resisting part, the brain is also covered by a triple membranous coat, formed by the *dura mater*, which takes its name from the erroneous opinion, that it gave origin to all other membranes of the body; the *arachnoides*, so called from the extreme tenuity of its texture, and the *pia mater*, that closely adheres to the substance of the cerebrum.

The dura mater not only lines the internal surface of the cranium and vertebral canal, which should be considered an elongation of it, but is also interposed between the different parts of the cerebral mass, supports it in various positions of the head, and prevents their mutual compression. It is on this principle that the most considerable of its elongations, the *falciform process*, extending from the *crista galli* of the ethmoid bone to the internal occipital protuberance, prevents the two hemispheres of the brain, between which it is placed, from pressing on each other when we are lying in a lateral posture, and also keeps the tentorium of the cerebellum in a state of necessary tension to support the weight of the posterior lobes of the *cerebrum:* this second process, of a semicircular form, *tentorium*, separates the portion of the cranium that contains the cerebrum from the inferior occipital fossæ, in which the cerebellum is situated. As it is stretched by the falx of the cerebrum, which, on the other hand, it serves to extend it does not offer an horizontal plane to the portion of this latter viscus that presses on it, but is inclined from all parts towards the parietes of the cranium, and transmits to them the principal part of the weight supported. The tentorium, that divides the internal cavity of the cranium into two unequal portions, is bony in certain animals, the motions of which are effected by leaps or sudden actions: in the cat, for example, that can make extraordinary jumps without being giddy. In consequence of this exact separation, tne two portions of the cerebral mass cannot act on each other in the violent commotion they must necessarily suffer.

The arachnoid membrane, according to *Boun*, who perfectly understood its distribution, and has given a very fine engraving of it, is the secretory organ of the serosity that moistens the internal surface of the dura mater, a fibrous membrane that serves as a periosteum to those bones, the internal surface of which it covers.

On the Size of the Brain.

CV. Man, of all animals, has the greatest cranium relative to the size of his face; and as the volume of the brain is always proportioned to the magnitude of the bony cavity, man has also the largest brain. This difference of extent between the cranium and the face well expresses the extent of understanding in man, and of instinct in animals: the stupidity of the latter and their ferocity are by so much the more marked, as the proportions of the two parts of their head are distant from the proportions of the human head.

Professor Camper, to express this difference of extent, has supposed a vertical line descending from the forehead to the chin, and falling perpendicularly on another horizontal line taken in the direction of the basis of the cranium. He has denominated the first of these the *facial*, the second the *palatine*, or line of the chin. It must be easily perceived, that as the projection of the forehead is determined by the magnitude of the cranium, the greater the extent of this, the more open will be the angle in which the facial line meets that parallel with the basis of the cranium. In a well-formed European head, the facial line meets the other at almost a right angle (of 80 or 90 degrees): when the angle is entirely rectilineal, and that which passes down the face completely perpendicular or vertical, the head has the finest possible form: it is nearer to the degree of perfection we form of ideal beauty. If the facial line be directed backwards, it then forms with the palatine an angle more or less acute, and projecting forwards; the inclination augments, the sine of the angle diminishes; and if we pass from man to apes, and then to other quadrupeds, to birds, reptiles, and fish, we find this facial line more and more, and to become ultimately almost parallel to the palatine, as in reptiles and fish with a flat head. If, on the contrary, we ascend from man to the gods, the images of which have been transmitted to us by the ancients, we find the facial line incline in an inverse direction; the right angle augments, and becomes more or less obtuse. There results from this inclination of the facial line forwards an air of grandeur and majesty, a projecting forehead, indicating a voluminous brain and superior understanding.

For the respective dimensions of the cranium and face to be demonstrated with precision, it is not only necessary to measure the external, but also to take the tangents on the internal surfaces, after having made a vertical section of the head. There are, indeed, certain animals, the frontal sinuses of which are so large, that a considerable part of the parietes of the cranium is distended by the cells arising from them: the apparent magnitude of the cranium in this respect in the elephant, dog, &c. is far superior to its real capacity.

The relative size of the head, and consequently proportional volume of brain, is not considerable in tall and very muscular subjects: this observation is easily verified by the examination of antique statues. All those which represent athletic persons or heroes, celebrated in fabulous history for prodigious power, have a head of small dimensions when compared with the whole mass of the body: in the statues of Hercules it is hardly equal to the top of the shoulder. The statues of the superior gods alone present the extraordinary assemblage of a vast head reposing on a body, the members of which bear a relative proportion; but the Greek artists have only transgressed the laws of nature in favour of the God that governed, implying that a vast brain was necessary for him whose intelligence could comprehend the whole plan of the universe by a glance. This relative smallness of the head of athletics, arises from the excessive development of the organs of motion in individuals of this constitution, which gives the body, particularly the limbs, an enormous magnitude, while the head, almost destitute of muscles, remains very small. Sœmmering has affirmed that the head of women is larger than that of men, and their brain more ponderous: but this great anatomist has drawn the fact from a male and female subject of the same height. But when the absolute magnitude is equal, the relative is not so; and he has deceived himself in comparing the head, cranium, and brain of a large woman with similar parts of a small man.

It has been long considered that there existed a necessary connexion between the volume of the cerebral mass and the energy of the intellectual faculties; it has been a subject of remark, that, in general, men of greater sensibility, whose genius is capable of the most surprising and vast conceptions have a large head with a short neck: the exceptions to this rule are so numerous, that many have doubted of its existence. Should it be absolutely rejected? and will not some foundation be admitted if we consider that man, the only being that possesses reason among so many others, some of which have so great a resemblance in organization and structure, is also that being, the cerebrum of which, strictly speaking, is the largest in proportion to the cerebellum, the medulla spinalis, nerves, and other parts of the body? Why should it not take place with the brain as with all other organs, which perform their functions so much the better as their development may be more complete? In this comparison of the brain and intellectual powers, we should remember that several causes may give this viscus an apparent magnitude; and that thus in subjects of a phlegmatic temperament, the tardy ossification of the bones of the cranium causes the head, distended by aqueous fluids, to acquire considerable bulk without containing a greater proportion of medullary substance: therefore it is remarked that persons of this temperament are frequently incapable of mental exertions, and seldom succeed in those things which require activity joined with perseverance.

I have no doubt but that the influence of the physical organization on the intellectual faculties may be so well marked, that we may consider as possible the solution of the following problem, analogous to that by which Condillac terminates his book (*l'Origine des Connoissances humaines*): The physical man being given, to determine the character and extent of his mind, and to draw an inference, not only what may be the talents of which he can give proofs, but also what those are which he may be able to acquire. The profound meditation of the work of Galen (*Quod animi mores, corporis temperamenta sequantur*); reading the Lives of illustrious Men by

Plutarch; the Panegyrics of Fontenelle, Thomas, d'Alembert, Condorcet, Vicq-d'Azyr, &c.; the medico-philosophic works of Cabanis, Hallé, Pinel, will be of great utility in the prosecution of this investigation.

"Philosophy," says the eloquent Dupaty, with the noble enthusiasm that struck him at the sight of the treasures accumulated by Fontana, in the Anatomical Museum of Florence, "philosophy was wrong not to descend further in physical man; it is there where moral man lies concealed: the external is only the projecting part of the internal man." *Thirty-third Letter on Italy.*

The Structure of the cerebral Mass.

CVI. What we already know of the brain only serves to prove that we are still ignorant of the more considerable part of it. Every thing we are in possession of, is reduced to correct notions of its external form, colour, density, and arrangement of different substances that enter into its composition; but the secret of its more intimate structure is still a mystery that will not be so soon discovered. The brain, strictly speaking, is divided by a longitudinal depression into two hemispheres of equal size; yet Gunzius has considered the right hemisphere a little larger than the left: but even if this assertion were as certain as it is doubtful, we could not by that explain the predominant power of the right side of the body, since the nerves distributed on this side come from the left hemisphere of the brain, in the substance of which the sources of these nerves decussate each other. This fact of the decussation of nerves is proved by a number of pathological observations, in which we always find an injury done to one lobe of the brain produce paralysis, convulsion, or any other symptomatic affection on the other side of the body: unless we choose to explain this phenomenon by admitting an equilibrium necessary in the action of both lobes; an equilibrium, the destruction of which induces that remaining healthy portion, by acting with greater force to compress the origin of nerves of its own side, and to produce palsy. Do the defect of judgment, inequalities of humour and character, depend on a want of harmony between the two correspondent halves of the cerebral mass?

Of the two substances that enter into the composition of the brain, the one is external, gray, cortical, or cineritious, forms a layer of several lines in thickness, and is only distinguished by its colour from the internal, which is a white, central, or medullary substance. In certain internal parts these two substances are mixed with each other, as the corpora striata, and thalami nervorum opticorum. The cortical substance seems to be formed of very minute vessels, which pass from the pia mater into the substance of the brain covered by this membrane: its nature is principally vascular; that, on the contrary, of the white substance seems highly nervous. Distinct fibrous packets are seen in the latter substance, particularly if we examine a brain indurated by immersion in oxygenated muriatic acid. Are the medullary fibres an immediate continuation of vessels in the cortical substance? Are the nerves constituted merely by an elongation of these fibres from the brain, and enveloped in a membranous sheath furnished by the pia mater? It is always found that the cortical substance seems less essential than the medullary; that the former is almost insensible; and that large portions of it may be removed without danger of life, as occasionally seen in certain wounds of the head, accompanied with injury to the brain; while the medullary substance cannot be touched without pain, and a sacrifice of the life of the animal on which the experiment is tried. The pain and danger are greater in proportion as we approach the white parts that are situated in the basis of the cranium, and the animal ultimately expires in the most acute pain and violent convulsions when we touch the annular protuberance of the medulla oblongata, called pons Varolii.

This medullary structure is formed by the concourse or union of the peduncles of the cerebrum and cerebellum; it has a common relation to both organs, and seems to be the most essential part of the cerebral mass: from this part arise the medulla oblongata et spinalis. Although the perforation of any instrument into the internal cavities of the brain; an injury done to any one of its protuberances, or to its commissures that form the parietes of the ventricles, or that part of the medulla oblongata or spinalis, above the two first vertebræ; cause the strongest animal to perish amidst convulsions, yet death is never more speedily produced than by an injury of the annular protuberance.

The cerebral Circulation.

CVII. It has been observed that the blood in its circular course does not pass through the different parts of the body with uniform celerity; that there existed partial circulations in the general circulation. The laws to which this function is subject are in no organ modified in a more remarkable manner than in the brain; there is no part, in proportion to its magnitude, that receives larger and more numerous arterial vessels than those which pass to the brain. The internal carotid and vertebral arteries, as affirmed by Haller's calculations, carry a great part of the whole mass of blood, (between two thirds and a half) that flows into the aorta.

The blood, which is carried to the head, says Boerhaave, is more aerial than that which is distributed to other parts; and this observation is far from being destitute of foundation. Although the blood, propelled by the contractions of the left ventricle into the vessels arising from the arch of the aorta, do not experience at this curvature a mechanical distribution that carries its lighter part towards the head, yet it is not less true that the blood, which has so recently received the contact of air in the lungs, should possess in the highest degree the properties of arterial blood. So great a quantity of light, red, frothy blood, impregnated with caloric and oxygen, arriving in the head with all the force impressed on it by the action of the heart, would have inevitably deranged the soft and delicate structure of the brain, if nature had not multiplied its precautions to diminish this impulsive force.

The blood, obliged to rise contrary to its specific gravity, is thus deprived of a part of its motion, the columna vertebralis strikes the angular curvature formed by the internal carotid in passing through the bony canal in the petrous portion of the temporal bone; and as this curvature, supported by hard parts, cannot be changed, the column of blood is deranged and turned from its primitive direction, which occasions a considerable diminution of its celerity.

The artery, surrounded with blood in the cavernous sinus at its exit from the carotid canal, is very dilatable; and the branches into which it divides, when in the basis of the cerebrum, are furnished with such delicate and weak parietes, that they collapse when empty like the coats of veins. Besides, these branches, as well as the ramifications arising from their division, are situated in depressions on the surface of the basis of the brain, and do not penetrate into its substance until reduced to a state of extreme tenuity by their subsequent divisions in the pia mater.

Therefore the blood is carried to the latter organ by a very retarded motion, notwithstanding the proximity of the heart and the brain; and, on the contrary, it returns by a motion progressively accelerated. The situation of veins on the superior part of the brain, between its convex surface and the arch of the cranium, causes these vessels which are gently compressed in the alternate motions of elevation and depression of the brain, to be emptied with facility into the membranous reservoirs or sinuses of the dura mater: these, by communicating together, offer a large cavity, from which it passes into the great jugular vein destined to return it into the circulating mass. This vein is not only of considerable dimensions, its parietes are likewise thin, very extensible, and its dilatability so great, that, when injected, it becomes larger than the vena cava: the passage of the blood is facilitated by its specific gravity, which renders retrogradation difficult.

The internal surface of the jugular vein is entirely destitute of valves, nor would they sufficiently oppose its reflux; but to obviate this inconvenience, both the direction of the blood and the great extensibility of the vascular parietes are completely adequate. The large diameter that the vena cava is capable of obtaining would have rendered valvular plicæ unnecessary, which could not have closed the canal when its dimensions were so materially augmented.

But to resume every thing relative to the particular mode of cerebral circulation: the brain receives a great quantity of rich, oxygenated blood: this fluid meets with many obstacles that retard its course, by diminishing its impulsive force; every thing, on the contrary, facilitates its return, and prevents venous distention.

The transverse anastomoses of arteries situated in the basis of the cranium, are well adapted to distribute the blood equally in every part of the viscus.

The connexions between the Action of the Brain and that of the Heart.

CVIII. Agreeably to the experiment of Galen, we may make a ligature on each of the carotid arteries of a living animal without its being sensibly affected; but if we tie the vertebral arteries at the same time, the animal instantly falls, and expires in a few seconds. To make this experiment, after having made the ligatures on the carotids of a dog, it will be necessary to remove the soft parts that cover the lateral surfaces of the neck, then to take up the arteries with semicircular curved needles, passed by the sides of the cervical vertebræ through their transverse apophyses: the ligature of the trunk of the ascending aorta of an herbivorous quadruped produces the same effect, that is, a sudden death of the animal.

These experiments, several times repeated, prove, in a decisive manner, the necessity of the action of the heart on the brain for the preservation of life. But what is the mode of action? Is it merely mechanical? Does it only consist in the light pressure that the arteries of the brain exert on its substance? or is it rather to be attributed to the interception of arterial blood that the contractions of the heart propel towards the brain, that induces death? The latter opinion seems to be most probable; for if we liberate the carotids at the same instant that we tie the vertebral, and, adapting the tube of a syringe, propel any liquid with a moderate force at intervals corresponding to those of the circulation, the animal does not recover life.

The heart and the brain are therefore connected together by a direct dependence. The continual arrival of blood that flows in the arteries of the head, is consequently necessary for the preservation of life: its momentary interception certainly occasions the death of the animal.

The energy of the brain seems generally in proportion to the quantity of blood received. I am acquainted with a literary character, who in the warmth of his composition presents evident symptoms of a species of brain fever. The face is red and animated, the eyes sparkling, the carotids beat forcibly, the jugular veins swell; every thing serves to indicate that blood is carried to the brain in an abundance and rapidity proportioned to the degree of excitement. It is only in this kind of erection of the cerebral organ that his ideas flow without efforts, and his imagination traces at pleasure the most agreeable pictures. Nothing so much favours this state as long-continued lying: in the horizontal position the determination of humours towards the head is by so much the easier, as the external organs are at perfect rest, and do not alienate its course; and to induce it nothing more is requisite than to fix his attention on an object. Should not the brain, which is probably the seat of this intellectual exertion, be considered the centre of fluxion? and may not the mental stimulus be compared, from its effects, to any other stimulus, either chemical or mechanical?

A young man of a sanguineous temperament, subject to inflammatory fevers, which always terminated by a copious hæmorrhage from the nose, suffers a remarkable augmentation in the power of his understanding and activity of his imagination during the paroxysms. Some authors had already observed, that certain febrile affections of a patient of a very moderate share of understanding, gave rise to ideas that in a state of health would have surpassed his conception. Cannot these facts be ranged in opposition to the theory of a celebrated physician, who considers the diminution of energy in the brain as the essential character of fever?

It is known that the different length of the neck, and consequently the greater or less proximity of the heart and brain, furnishes us with a tolerable idea of the understanding of men, and the instinct of animals. An extreme length of the neck has been at all times considered the emblem of stupidity.

In the present state of our knowledge, can it be determined in what manner arterial blood acts upon the brain? Do not the oxygen or caloric, of which it is the vehicle, when elaborated by this viscus, become the principle of sense and motion? or, at least, do they only maintain it in the degree of consistence necessary for the exercise of its functions? What ought we to think of the opinion of some chemists, who only consider the cerebral organ as an albuminous mass concreted by oxygen, the consistence of which is variable according to the age, individual, sex, state of health or disease? Every answer to these premature questions could only be conjectural, and difficult to furnish with any degree of probability.

The Theory of Syncope.

CIX. If we reflect on the importance of the action that the heart exerts on the brain, we are naturally led to admit the necessity of it for the preservation of life, and from its momentary suspension to deduce the theory of fainting. Some authors have already endeavoured to explain the mode of action from the proximate cause; but as none are derived from facts demonstrated by experience, their explanations are by no means consonant with observation on the phenomena of similar affections.

To be convinced that an instantaneous cessation of the action of the heart on the cerebral organ should be considered the immediate cause of syncope, it is only necessary to peruse with attention the chapter that Cullen, in his Nosology, has written on these kinds of affections; we shall clearly perceive that their occasional causes, the varieties of which determine their numerous species, are either inherent in the heart or large vessels, or exert their action about the epigastrium, and only affect the brain in a consecutive manner. On this principle, syncope produced by anneurismal dilatations of the heart and large vessels, by polypous concretions formed in these canals, by the ossification of their parietes or valves; faintings induced by dropsy of the pericardium, or by adhesion of the heart to the internal surface of this membranous sac; evidently depend on the extreme weakness or total cessation of the action of the heart. Their ossified, dilated parietes, adhering to the surrounding parts, or compressed by some fluid, no longer act on the blood with sufficient force; or this fluid is stopped in its progress by an obstacle distending the internal part of these canals, as a polypous concretion, a valve ossified or immovable. Cullen justly calls these species of syncope idiopathic or cardiac.

We may also adduce the plethoric syncope, which depends on a sanguineous congestion in the cavities of the heart: the contractions of this organ become more frequent, it redoubles the efforts to release itself from the superabundance that impedes the exercise of its functions; but a kind of a paralysis, of which syncope is a necessary consequence, soon succeeds this unusual excitement by which the irritability of its fibres is blunted.

The fainting fits produced by copious bleeding should also be considered: the sudden abstraction of a certain quantity of vivified fluid deprives the heart of a stimulus necessary for the preservation of its action. The same effect results from the evacuation of water from the cavity of the abdomen in ascites; the compression on numerous vessels ceases; the blood, which they hitherto refused to admit, rushes into them abundantly: the quantity sent from the heart to the brain being proportionally diminished, is no longer sufficient for its excitement. We might also rank among idiopathic syncope those which are present in the advanced stage of scurvy, the principal character of which is an excessive debility of muscles destined for the vital functions and voluntary motion; and, lastly, *asphyxia* by strangulation, submersion, non-respirable gas; affections in which the blood, being deprived of the principle that renders it adequate to induce contractions of the heart, the circulation is interrupted. We may conceive that if the blood only lose its stimulating qualities gradually, the action of the heart is proportionally diminished, propels towards the brain a blood that by its qualities is nearly related to venous blood, and which cannot maintain the cerebral mass in its state of natural economy.

A second order of occasional causes is produced by those which sympathetically induce a cessation of pulsations in the heart by carrying their action to the epigastrium, and induce syncope in consequence of this cessation, such as lively affections of the mind: for example; great terror, excessive joy, a peculiar aversion to certain food, surprise at seeing an unexpected object, the disagreeable impression of certain odours, &c. In all these cases the internal sensation of a greater or less commotion is perceived about the region of the diaphragm. Its effects are conveyed from the plexus of the great sympathetic nerve, which, according to the doctrine generally admitted, is considered to be the seat of this sensation, to the other abdominal and thoracic plexuses: the heart, which receives all its nerves from the great sympathetic, is particularly affected by it; its action is sometimes only disturbed, at other times entirely suspended; the pulse becomes insensible, the face pale, the extremities cold, and *syncope* takes place. A similar train of occurrences takes place when a narcotic or poisonous substance has been introduced into the stomach, when this viscus has been much weakened by long abstinence, or is loaded with crudities during intestinal pains called the *colic*, and in hysterical paroxysms.

This latter order of occasional causes only acts on the heart in a secondary manner, and indirectly produces syncope; but the result is always the same. It occurs in all cases; from the arteries of the head no longer receiving a sufficient quantity of blood, as carried to them in a natural state, the cerebral mass falls into a sort of collapse, which occasions a momentary cessation of the faculties of the understanding, of the vital functions, and of voluntary motion.

Morgagni, in treating of diseases of the head according to anatomical arrangement, places *lypothymiæ* among affections of the chest, because the viscera of that cavity demonstrate the existence of a greater or less diseased state in persons that had been frequently subject to these affections. A compression of the brain from a fluid extravasated on the dura mater, does not so much produce syncope as profound stupor: all causes that act in this manner on the cerebral organ are an abundant source of comatose, carotid, and even apoplectic affections.

I could support this theory of syncopal affections with other proofs, taken from circumstances that favour the action of causes which produce them. For example: it is mostly in an erect posture that faintings happen, and lying in an horizontal position is an useful precaution in the treatment of them. Patients afflicted with complaints of long standing fall into syncope at the instant they wish to rise, and are recovered by being restored to their former local situation. But how is this effect of standing explicable in subjects in whom the mass of blood is impoverished, and organic action extremely languid? Is it not in consequence of the more difficult return of blood carried to the inferior extremities, and of the less easy ascent of that fluid, propelled to the brain by the contractions of the heart? The phenomena of the circulation are, at that time, more hydraulic than in a state of health; the living solid more easily yields to the influence of physical and mechanical laws; and, according to the sublime idea of the father of medicine, our particular nature becomes more intimately related to universal nature.

The Motions of the Brain.

CX. Are the alternate motions of elevation and depression observed in the brain when divested of the cranium, exclusively concurrent with the pulsations of the heart and arteries? or do these actions correspond with the periods of respiration? We shall endeavour to explain this physiological problem.

The authors that have acknowledged the existence of motions of the dura mater, have not held the same sentiments on the cause which produced them. Some believed they saw moving fibres, and made these motions dependent on their action (Willis, Baglivi); others attributed them to the pulsation of arteries in its structure (Fallopius, Bauhine.) But the dura mater does not possess a contractile power; besides, its close adhesion to the internal surface of the cranium would impede the exercise of this faculty. The membrane is not actuated by the motion of its vessels; for, as Lorry observes, the arteries of the stomach, intestines, and bladder, do not impress any degree of motion on the parietes of those viscera; yet they are, at least, equal in number and size to those of the cerebral membranes.

The action of the dura mater is given by the mass of brain covered by this membrane; and this opinion of Galen, adopted by the greater number of anatomists, has been placed beyond all doubt by the experiments of Schlitting, Lamure, Haller, and Vicq-d'Azyr. On elevating the dura mater, they have all seen the alternate motions of elevation and depression in the brain: all of them, except Schlitting, have observed that the brain is totally passive, and received from its vessels those motions in which the dura mater participates. But are they communicated to it by the cerebral arteries or veins, and the sinuses in which they terminate? or, in other words, are they synchronous with the pulsations of the heart, or with the successive contraction and dilatation of the thorax during respiration?

Galen, in his book on the use of this function, says, that the air admitted into the pulmonary organ distends the diaphragm, and is carried into the brain by the vertebral canal, &c. According to his doctrine, the brain is elevated during the distention of thorax; it is depressed, on the contrary, when the parietes of this cavity return on their axis. Schlitting, in a memoir presented to the Academy of Sciences about the middle of last century, established the existence of these motions, but in another point of view; the elevation corresponding to expiration, and the depression to inspiration. After having confirmed the fact by a great number of experiments, he does not hazard any explanation, and concludes his researches by asking whether it be the air, or the blood carried to the brain, that may produce the different motions.

Haller and Lamure endeavour to give a solution of the problem. Both made a great number of experiments on living animals, proved the truth of the fact announced by Schlitting, and explained it in the following manner: As the latter anatomist, Lamure, admits the existence of a space between the *dura* and *pia mater*, by the medium of which the motions of the brain could be effected, the existence of this medium is negatived by the simple observation of the contiguity of the membranes, between which it was said to be placed.

During expiration, says Lamure, the parietes of the thorax return on themselves, and diminish the extent of the cavity; the lungs, pressed on all sides, collapse, the curvatures of their vessels augment, and the blood passes through them with difficulty. The heart and large vessels being thus compressed, the blood carried by the vena cava into the right auricle cannot be freely poured into this cavity, which is with difficulty emptied into the right ventricle, as the blood cannot thence pass into the structure of the lungs. On the other side, the lungs compressing the vena cava, there results a true regurgitation of that which it is carrying to the heart; being repelled into the jugulars and vertebrals, it distends these vessels, the sinuses of the dura mater, and the veins of the brain that empty themselves into these sinuses. Their distention explains the elevation of the cerebral mass, which is soon followed by a depression; when inspiration succeeds expiration, and the lungs come to be dilated, the blood that fills the right cavities of the heart can freely pass through their substance, and give place to that which the vena cava returns from the superior parts.

Haller considered this reflux as very difficult, the blood being obliged to struggle against its specific gravity, and only admits the explanation of Lamure for the great efforts of respiration, as coughing, laughing, sneezing, &c. He maintains that in the ordinary state during expiration, only a simple stagnation of blood was perceived in the vessels that convey it from the internal part of the cranium. He also admits, agreeably to the testimonies of a great number of authors, another order of motions dependent on pulsations of arteries; so that, according to Haller, the cerebral mass is continually agitated by motions, one kind of which are effected by respiration, the other entirely independent of it.

Finally, according to Vicq-d'Azyr, the brain, when laid bare, presents a double motion, or rather two species of motions, which are both distinct; one is induced by the arteries, and is less considerable, the other is produced by the alternate motions of respiration.

CXI. This diversity of sentiment in authors of equal respectability, whose theories are in universal repute, has induced me to repeat the experiments that each of them has adduced in support of his doctrine, and to submit the hitherto doubtful fact to fresh experiments. This examination soon convinced me that the authors had rather expressed their opinions than the fact itself. In fact, the alternate motions of elevation and depression in the brain are simultaneous with the systole and diastole of arteries situated in its basis: the elevation corresponds to the dilatation, and the depression to the contraction of these vessels. Respiration has no influence in these phenomena; and even admitting the stagnation or regurgitation of blood in the jugular veins, the disposition of venous ducts in the internal part of the cranium is such, that this stagnation or regurgitation could not produce the alternate motions on the mass of brain.

The arteries of the brain are supplied by the internal carotids and vertebrals; the first passing into this cavity by the carotid canals, the second by the great occipital foramina. It would be useless to describe their numerous divisions, frequent anastomoses, the arterial circle, or rather polygon formed by them, and by which the carotid and vertebral arteries communicate together on the sides of the *sella turcica*. (See Boyer, *Anatomie du Corps humain*, tom iii.)

Haller has given a very correct drawing and excellent description of it, (*Fasciculi anatomici*, fig. vii. tab. 1.) The history of the internal carotid, published by this anatomist, is, according to Vicq-d'Azyr, a masterpiece of erudition and exactitude: the same praises might be given to this latter gentleman, who has obliged the world with a most excellent engraving of it, (*Planches anatomiques: Cerveau* *de l'Homme, troisieme Cahier).* We shall only observe, that the principal arterial trunks carried to the brain are situated at the basis of that viscus; that the branches into which the trunks are divided, and their ultimate ramifications, are also placed in the basis of this viscus in numerous depressions; and, finally, that the arteries of the brain do not penetrate into its substance until they have suffered infinite divisions in the texture of the pia mater, which seems totally composed of them.

The vessels that carry back the portion of the blood which has not been employed for its nourishment and growth, are placed, on the contrary, towards its superior part, between its convex surface and the arch of the cranium. Each inequality or depression is there covered by a large vein that passes into the longitudinal sinus. The veins of Galen, which carry the blood distributed on the plexus choroides to the right sinus; some small veins that are evacuated into the cavernous and communicating sinus; some others also, though very small, passing through perforations in the alæ of the sphenoid bones, and assisting to constitute the venous plexus of the zygomatic fossa, are the only exceptions to this general rule.

Having said so much on the disposition of arterial and venous vessels that are distributed on the brain, let us examine what ought to be the effects of their action relative to this viscus.

The contractions of the heart propel the blood into arterial tubes, which undergo, particularly at their curvatures, an evident change of situation, and at the same time dilate. All the arteries situated at the base of the cranium experience both these effects at once; their united efforts produce a motion of elevation, to which succeeds depression, when by returning on themselves they react on the blood that distends them.

These motions do not take place when the cranium is entire. This cavity is too completely filled: there is no vacuity between the membranes of the brain. Lorry, who justly denied its existence, has committed an anatomical error not less considerable, when he affirmed that, as the tendency to motion could produce no effect on the sides next the cranium from its complete plenitude, it was performed by the ventricles, which he considers real cavities, but which, as demonstrated by Haller, are, in a natural state, only contiguous surfaces, simple parietes of the cavity in contact. This tendency to motion only becomes real action when a part of the parietes of the cranium is removed.

Yet we can conceive that the brain, being soft, may yield to the light pressure exerted by its arterial vessels. Does not this continual action of the heart on the brain satisfactorily explain the remarkable sympathy between these two organs, connected by such intimate means? It has also a very evident utility relative to the return of blood distributed to the cerebral mass and its coverings; the veins that return it, alternately compressed against the concavity of the cranium, empty themselves with greater facility into the sinuses of the dura mater, to which they are connected by a retrograde (obtuse) angle, unfavourable to the passage of the blood into them.

When any cause whatever impedes the free passage of the blood through the lungs, the fluid stagnates in the right cavities of the heart; the vena cava superior, internal jugulars, and consequently sinuses of the dura mater and veins of the brain, emptying themselves into these sinuses, are gradually distended; and if this dilatation were carried to a certain degree, the cerebral veins situated between the brain and arch of the cranium would have a tendency to depress it towards the basis of this cavity; and if the dilatation, at first light, were to extend beyond the extensibility of its vessels, their rupture would give place to fatal extravasations. Authors have thus explained sanguineous apoplexy.

It will, perhaps, be objected, that several sinuses of the dura mater are situated in the basis of the cranium, and therefore their dilatation should be disposed to elevate the cerebral mass.

But the generality of these sinuses are only connected with the cerebellum and medulla oblongata, the motion of which has not hitherto been observed: these sinuses are chiefly situated on the edges of the falciform process, and the tentorium of the cerebellum. The cavernous sinus, into which the ophthalmic vein empties itself, the communicating sinuses that permit the blood to pass from each other, are too inconsiderable to produce an elevation of the mass of brain. Finally, the resistance of their parietes, principally formed by the dura mater, should give a narrow extent to their expansion: the spongeous texture that fills the internal part of the cavernous sinuses, also renders this dilatation and the reflux of the blood more difficult.

CXII. It is not sufficient to prove, by reasons drawn from the disposition of parts, that the motions of the brain are communicated by the aggregation of arteries placed at its basis: this fact must also be established on observation, and rendered incontestable by positive experiments. To attain this object I have instituted the following:

A. I have first repeated the observation of some authors, and, like them, found that the pulsations perceived by placing the finger on the fontanellæ of the cranium of new-born infants, perfectly correspond to those of the heart and arteries.

B. A patient trepanned for a fracture of the cranium, and effusion under the dura mater, presented me with a brain rising and sinking alternately. The elevation corresponded to the diastole, the depression to the systole of arteries.

C. Two dogs trepanned offered the same phenomenon with respect to the dilatation and contraction of these vessels.

D. I carefully removed the arch of the cranium in the body of an adult; the dura mater, detached from its adhesions with the bones it covered, was preserved entire. I afterwards laid bare the trunks of the carotids, and injected water into these vessels. At each stroke of the piston the brain had a very conspicuous motion of elevation, particularly when the liquid was, at the same instant, propelled into both carotids.

E. I have injected the internal jugular veins; the mass of brain remained in a state of quiescence: only the veins of the brain and sinuses of the dura mater were dilated. The injection was retained for some time, a little swelling of the brain was perceived; when pushed with greater force some veins ruptured, and the liquor escaped: the same kind of injection was made with water tinged to a deep red, which colour was very evident on the surface of the brain. To perceive this effect more completely, after having removed the arch of the cranium, we should make an incision on each side of the dura mater, parallel to the circular incision of the bone, and then elevate its edges towards the superior longitudinal sinus.

F. The internal jugular veins being laid open during the injection of the trunks of the carotid arteries, each stroke of the piston causes the fluid to gush out with great force; a very evident proof of the influence exerted by the motions of the brain on the passage of blood in its veins, and in the sinuses of the dura mater. This experiment has been already made by other anatomists, and among them Ruysch, with intention to prove a direct communication between arteries and veins: this is at present generally omitted and demonstrated by other facts. It will be perceived that the following is no less conclusive:

G. I have tied the carotids successively in a trepanned dog; the motions of the brain diminished, but did not entirely cease. The anastomoses of the vertebral, with branches of the carotid arteries, account for this phenomenon.

H. I took a rabbit, a tame animal easily confined, and very convenient for difficult experiments; after having laid bare the brain, and observed that its motions were exactly correspondent to pulsations of the heart, I made a ligature on the trunk of the ascending aorta: at the instant the blood ceased to be carried towards the head, the brain no longer had any motion, and the animal expired.

I. The ligature of the internal jugular veins did not occasion a loss of motions of the brain; but its veins are dilated, and its surface, uncovered by removing a portion of the dura mater, appeared redder than in a natural state. The dog fell into a state of coma, and expired in convulsions.

The opening of these veins did not prevent the motions from continuing; they only became weaker when the animal was debilitated from the hemorrhage.

K. An opening of the longitudinal sinus, which is the only one that could be effected, does not weaken the motions of the brain. It is observed that the blood flows out of it more profusely during the elevation.

L. The compression of the thorax of the human body only produces a slight reflux into the jugular veins, particularly if the trunk be elevated during this compression. The reflux is more easy and evident when the body is placed in an horizontal posture.

These experiments might be still varied and augmented; for example, by pushing an injection into the carotid and vertebral arteries at the same time: but those which I have already enumerated are adequate to elucidate the desired object.

Since the time of the first publication on this subject, in the collection of Memoirs of the Medical Society *(Mémoires de la Société Medicale de Paris, An 7, troisieme Année,* p. 197 *et suiv.)*, I have had several opportunities of repeating the observations and experiments that serve to support the theory here proposed. There is one among these decisive facts that merits particular attention; this alone would be sufficient, if possible to establish a theory on one observation. A woman about fifty years of age had an extensive caries on the cranium; the left parietal bone was destroyed throughout the greater part of its extent, and left a considerable part of the dura mater bare: nothing was more easy than to witness a perfect correspondence between the motions of the brain and beating of the pulse. I requested the patient to cough, and suspend respiration for an instant: the motions retained the same connexion. In the efforts of coughing the head was agitated, and the general concussion in which the brain participated might have imposed on a prejudiced observer for motions peculiar to this organ, and dependent on the reflux of blood in the venous vessels.

In the experiments on dogs, the same motion takes place; when the animal barks, it is easy to observe that the concussion the brain suffers is felt throughout the body, which the effort of expiration necessary for barking determines in a more or less violent degree.

The patient who was the subject of the preceding observation, died about a month after my appointment at the hospital of the North, where she had been for a long time. On opening the body, the left lobe of the brain was found softened, and a kind of putrid reservoir; the ichor, which it furnished in abundance, flowed out by a fistulous orifice of the dura mater, the substance of which membrane was a little thickened.

CXIII. The soft substance of the brain, which Lorry considered as favourable to the communication of the motion impressed by arteries, seems, in my judgment, to be an obstacle to this transmission. In fact, the dilated vessels not being able to depress the basis of the cranium on which they are situated, exert their efforts upon the cerebral mass, and elevate it with the greater facility (when the arch of the cranium is removed), as it may offer a certain resistance. If the brain were too soft, the artery would plunge into its substance, and would not move the whole mass. To be convinced of this truth, it is sufficient only to attend to what happens when the posterior part of the knee (the ham) is reposed on a pillow, or any similar body; the motions of the popliteal artery communicated to the limb are not then so perceptible; on the contrary, they become very apparent when the ham leans on a surface that offers a certain resistance, as on the other knee; then the artery which cannot depress it employs all its action to elevate the inferior extremity, which is more easily effected when it acts against a hard, resisting, and bony part. This experiment completely overturns the opinion of Lorry. The deficiency of analogy will not be considered as an objection; it will not be said that the brain is heavier than the inferior extremity, nor that the combined diameter of the internal carotid and vertebral arteries is superior to that of the popliteal artery.

This continual tendency that the brain possesses to elevate itself, ultimately produces marked effects on the bones of the cranium that are opposed to its motion: thus the internal surface of these bones, smooth in the first moments of life, are furrowed more deeply in proportion to the advance of age. The digital depressions and mammillary eminences corresponding to the convolutions and anfractuosities of the brain, are very evidently the produce of its action on the parietes of the cavity in which it is inclosed. Sometimes it happens that in very advanced age the bones of the cranium are rendered so thin by this kind of internal encroachment, that the pulsations of the brain become evident through the hairy scalp.

There is no doubt but that the same cause accelerates the destruction of the cranium by fungous excrescences of the dura mater: the expansive effort of the tumour also assists and renders the wear of the bone more rapid. At the expiration of some months the tumour is perceptible externally, and then presents pulsations evidently synchronous with the beating of the pulse, as Louis observes in a memoir inserted among those of the Academy of Surgery.

I have proved (CXII.) that the disposition of the veins of the brain, and of the sinuses of the dura mater, were opposed to the action on this viscus, attributed to them. The experiment E. L. proves that the stagnation of the blood, or even the reflux of this fluid, could only produce the slow and gradual distention of the sinuses of the dura mater, of the veins that are emptied into them, and a slight turgescence of the brain itself, if the cause that produced this retardation or retrocession of the blood protracted its action, and the cranium were in part destroyed.

Finally, the alternate motions of the brain, which are said to correspond to those of respiration, should be, with respect to the beating of the pulse, as one to five: it is, on the contrary, easily proved that these motions are in an inverse proportion, and perfectly consonant with the pulsations of the heart and arteries.

The results of experiments advanced in this memoir, when compared with those of respectable authors, presented differences too obvious to pass over without endeavouring to investigate their cause; for which purpose I have thought it necessary attentively to examine all the circumstances.

The work of Lamure contains anatomical errors which make us doubt of its exactness. Haller did not make the experiments himself of which he speaks, in treating on the influence of respiration on the circulation of venous blood: this article is taken from a thesis presented at Gottingen by one of his pupils. Vicq-d'Azyr has not risked any confirmative experiment, and seems only to have attempted to conciliate all the opinions.

None of these anatomists have distinguished the motions of elevation impressed on the cerebral mass by the propulsion of arteries, or the swelling of the sinuses of the dura mater, and of the veins and slight tumefaction of the brain, that may result from an impediment to respiration. This want of observation was more likely to happen, since animals suffering under the scalpel of the anatomist have a respiration unequal and convulsive, the periods of which have shorter intervals than in a natural state. Schlitting, the first author of these experiments, seems to have confounded the motion of elevation, and the change of situation in the brain, with the turgescence of this viscus. In each expiration, says he, I observed the brain elevate, and in each inspiration I saw it descend, that is, diminish. "*Toties animadverti perspicuè . . . . in omni expiratione cerebrum universum ascendere, id est intumescere; atque in quavis inspiratione illud descendere, id est detumescere.*"

We may consider the following proposition as a truth rigorously demonstrated by observation, experience, and reason:

The motions presented by the brain, when laid bare, are exclusively communicated to it by the pulsations of arteries situated at its basis, and perfectly correspond with the beatings of the pulse.

Action of Nerves and of the Brain.

CXIV. It is beyond a doubt, as Vicq-d'Azyr observes, that nerves act by a motion, whatever that may be. In proceeding with this simple idea, we may distinguish several kinds of nervous motions; one is carried from the circumference to the centre: it is the motion of sensation that we are particularly to consider in this paragraph: the other, from the centre to the circumference; and this motion produced by the will determines the action of muscular organs, &c.

By what means are impressions produced on the senses by surrounding bodies, transmitted along the nerves to the brain? Is it through the intermedium of a fine fluid? or may the nerves, as several physiologists have believed, be considered as vibrating chords? The latter hypothesis is so absurd, that we may be surprised at the long confidence it has obtained: for a chord to execute vibrations, it should be stretched throughout all its extent, and confined at both ends. The nerves are not stretched; their extremities are by no means confined, they approach and recede from each other according to the different position, tension, swelling, repletion, or collapse of parts, and continually vary the distance: besides, nervous chords situated between two pulpy extremities, at their origin and termination, cannot be stretched between these points. The nervous fibre is the softest and most elastic of all animal fibres.

When a nerve is divided, its two extremities, instead of contracting, both elongate: the point of section presents several small medullary projections, formed by the nervous and white substance that flows in its membranous canals. Besides, the nerves, surrounded by parts to which they are united, could not perform vibrations; and, finally, admitting their possibility, the vibration of a single surculus should occasion that of all the others, and produce confusion and disorder in motions and sensations.

It is more reasonable to believe that nerves act by means of a subtile fluid, invisible and impalpable, to which the ancients gave the denomination of *animal spirit.* This fluid, unknown in its nature, appreciable only by its effects, should be of extreme tenuity, since it eludes every method of detection. Does it come entirely from the brain? or is it alike secreted by the membranous coverings of each nervous filament? (*Neurilemes*, *Reil.*) Amongst the constituent principles of the atmosphere there are some fluids generally expanded, as electricity and magnetism. Cannot these fluids, having passed with the air into the lungs, be combined with arterial blood, and be carried by means of it into the head or other organs? does not vital action invest them with new properties, by causing them to experience unknown combinations? do caloric and oxygen enter as component parts in these combinations that alter the nature of the fluid, vitalize it, and impress on it essential and incalculable differences? have not these conjectures acquired a certain degree of probability since the analogy of Galvanism with electricity, at first presumed by the author of this discovery, has been confirmed by the very curious experiments of Volta, repeated, commented on, and explained at this moment by all the philosophers of Europe?

The action of the nervous fluid passes from the extremity of nerves towards the brain, for the production of the phenomena of feeling, since the ligature of nerves destroys the sensibility of parts situated below this ligature, while this action is propagated from the brain towards the nervous extremities, and from the centre to the circumference, to produce motion of various kinds. This double passage, in a contrary direction, may take place along the same nerves; and there is no necessity to make two classes, and distinguish them into nerves of *motion* and of *sensation*.

All impressions perceived by the organs of sense, by the percipient extremities of nerves, are transmitted to one point in the cerebral substance. It is here that exists the *sensorium commune*, placed by Des Cartes in the pineal gland, the use of which is unknown; and by La Peyronie in the *corpus callosum*, which serves as a medium of union between the medullary substances situated in the centre of each of the hemispheres of the brain, and which to us seems rather to have its seat in the annular protuberance, a confluence to which productions from the cerebrum and cerebellum unite.

The existence of a central point to which all sensations are carried, and from which all motions emanate, is necessary to the unity of a living animal, to the harmony of its functions; conditions without which it would soon cease to live.

Analysis of Sensations and Ideas.

CXV. Our ideas only come to us by the medium of the senses: none are innate. The infant is disposed to acquire them in proportion as it is sensible, that is, susceptible of being impressed by surrounding objects. A being, absolutely destitute of sensitive organs, would have an existence merely vegetative; if he had one sense he would not possess understanding, since impressions produced on this only sense, as proved by Condillac, could not be compared; all would be circumscribed in an internal sentiment that would inform him of its existence, and he would believe that every thing that had an influence was a part of himself. This fundamental truth, so completely developed by modern metaphysicians, is found formally declared in Aristotle (*Nil est in intellectu quod non prius fuerit in sensu*); and it is really surprising that it has been neglected during so many centuries. It is so true that sensations should be considered as furnishing us with the matter of all our knowledge, that the understanding is in proportion to the number and perfection of the organs of sense; and that by successively depriving the being of their possession, we should gradually diminish its intellectual nature; while the addition of a new sense to those we already possess might lead us to a multitude of ideas and sensations unknown to us, would cause us to discover in objects that interested our attention a great number of new relative connexions, and very considerably augment the sphere of our understanding.

Those who still admit the hypothesis of innate ideas, advance an observation of Galen, which appears to me so improbable, that it is really surprising that any person should have any doubts on the subject. He took a kid from the belly of its dam, and after offering several kinds of herbage, found that among other vegetables it preferred the broom-tops (genista). If such a fact have any reality, we should be forced to admit that an animal may possess anticipated knowledge of what is proper for it; and that, independently of impressions that may be afterwards received by the senses, it is capable, from the moment of birth, to choose, that is, to compare and to judge of what is presented. But it is only long after birth, and after having exercised its senses, that a kid is able to graze, and to select from among various herbs those which are most agreeable. Soon after being foaled it is enveloped in mucus, incapable of extensive motion, and only seeks milk, which alone it is capable of digesting, and which is destined to serve for aliment until the masticatory organs are sufficiently developed.

The impression produced on any organ by the action of an external body constitutes *sensation*. This sensation, transmitted by nerves to the brain, is *perceived;* that is, felt by that organ: the sensation then becomes perception, and this first modification implies, as must be evident, the existence of a central organ, to which impressions produced on the senses are conveyed. The cerebral fibres are acted on with greater or less force by the sensations propagated by all the senses influenced at the same time; and we could only acquire confused notions of all bodies that produce them, if one particular and stronger perception did not obliterate the others, and fix our attention. In this collective state of the mind on the same object, the brain is weakly affected by several sensations which leave no trace behind: it is on this principle, that, after having read a book with great attention, we forget the sensations produced by the different colour of the paper and characters.

When a sensation is of short duration, the knowledge we have of it is so weak, that soon afterwards there does not remain any remembrance of having experienced it. Thus we do not perceive that at every instant, and so often as we twinkle the eyelids, we pass from light to darkness, and return from darkness to light: if we fix our *attention* on this sensation, it strikes us in a permanent manner. When we are employed during a given time in many things, on each of which only moderate attention is bestowed; for example, when we have read a novel full of a great number of anecdotes, each of which, in its place, has interested us, we finish it without being fatigued, and we are surprised at the time employed in reading it: it is because the successive and short impressions have in general obliterated each other, and we have forgot every thing except some principal actions. The time should then seem to have passed with rapidity; for as Locke, in his Essay on the Human Understanding, has justly observed, *we only conceive the succession of times by that of our thoughts.*

This faculty of occupying one's self for a long time, and exclusively, on the same idea, of concentrating all the intellectual faculties on the same object, of directing to its individual contemplation a lively and protracted attention, exists to a greater or less degree in different persons; and some philosophers seem to have reasonably explained the varied extent of capacities, and the different degrees of instruction of which we are capable, by the degree of attention we are able to bestow on those things which constitute the object of our study.

Who gives more attention to the examination of one and the same idea than a man of genius, reflects on it more deeply, and better considers it under all its points of view and connexions, and, in a word, affords it more attention?

In proportion as a sensation, or an idea, which is only a sensation transformed or perceived by the action of the cerebral organ, has produced in the fibres of this organ a stronger or weaker impression, the remembrance of it becomes more lively and permanent. Thus we may have a *reminiscence* of it, that is, call to mind that we have already been affected in the same manner; a *memory*, or the act of recalling the object of the sensation, with some of its attributes, as colour, volume, &c.

It would be very absurd to believe that the pains perceived in limbs that we no longer retain, have their seat in that portion which remains; thus the brain is deceived in referring to the foot uneasy sensations, the cause of which exists in the stump after amputation of the leg or thigh. I have now under observation the example of a woman and a young man, whose leg and thigh I amputated for a scrofulous caries, incurable by any other method, and which had existed several years. The wound, from the operation, is completely cicatrized; the stump does not possess greater sensibility than any other part, covered by the common integuments, since it can be handled without causing pain; yet both, at intervals, paticularly when the air superabounds with electricity, complain of perceiving it in the extremities, of which for some months they have been absolutely deprived. These pains, like all perceptions, evidently arise from memory, which reproduces them when the cerebral organ repeats the motions which it exercised during the disease.

In fact, if the brain be easily excitable, and at the same time accurately preserve impressions received, it possesses the power of representing to itself ideas with all their connexions, and all the accessory circumstances by which they are accompanied, of reproducing them in a certain degree, and of recalling an entire object, while the memory only gives us an idea of some of its qualities. This creative faculty is called *imagination:* if it produce monsters, it is because the brain, which can associate, connect, and combine ideas, produces them in an order of succession that is not natural, classes them according to the dictates of caprice, and gives rise to many false judgments.

When two ideas are brought together, compared, and their analogy considered, we are said to form a *judgment:* several judgments connected together constitute *reasoning.* To reason, therefore, is only to judge of the relations that exist between ideas furnished by the senses, or reproduced by the imagination.

The faculties of the mind are like those of the body: if we exert the intellectual organ, it acquires a degree of force, and languishes after too long repose; if we only employ certain faculties, they acquire a great development to the prejudice of others. Thus by the study of the mathematics we form a solid judgment and correct reasonings, while the imagination is confined, and never obtains great influence without being conformable to judgment and reasoning: descriptive sciences particularly occupy the memory, and seldom afford a vast extent to the mind of those who cultivate them.

Besides the sensations that are carried from the organs of sense to the brain, there are others, internal, that seem to be transmitted to it by a kind of sympathetic reaction. It is well known what uneasiness the affection of certain organs conveys to the mind; how much an habitual obstruction of the liver is connected with a certain order of ideas: these internal sensations are the origin of our moral faculties, in the same manner as impressions that are conveyed by the organs of sense are the source of intellectual faculties. We are not, however, on that account, to place the seat of the passions of the mind in the viscera; and, like the ancients, to consider anger in the liver, joy in the spleen, &c.; it is only necessary to remember that the *appetites*, whence arise the *passions*, reside in these organs, and are a phenomenon purely physical, while passion consists at the same time in an intellectual exertion. Thus, an accumulation of semen in the cavities that are employed as a reservoir for it, excites the *appetite* for venery, very distinct from the passion of love, although it may be frequently the determinate cause of it. Animals have little more than *appetite*, which is as widely different from *passion* as *instinct* from *understanding*.

The affections of the mind or the passions, whether arising from the senses or any disposition of the vital organs assisting their origin or development, may be ranged under general classes relative to the effects they produce on the economy. Some augment organic activity, as joy, courage, hope, and love; others, on the contrary, retard vital motions, as fear, sorrow, and hatred; others, again, produce both these contrary effects alternately, or at the same instant: it is on this principle that ambition, anger, despair, pity, acquiring, like other passions, an infinite number of gradations, according to the intensity of their causes, the individual constitution of those whom they affect, their sex, age, &c. sometimes increase, at other times diminish vital action, depress or elevate the powers and organs.

Physiology has for its object the knowledge of the functions exerted by man, in a *physical* sense, the study of the finest part of ourselves, of those surprising faculties by which our species is above every thing that has motion and life: in fact, the knowledge of *moral* and *intellectual* man belongs to the province of metaphysics. The philosophic works of Bacon, Locke, Condillac, Bonnet, and the important memoirs published by Cabanis, on the influence of age, sex, temperaments, &c. on the origin and development of the moral and intellectual faculties, may be consulted with advantage.

Sleep and Watching.

CXVI. Sleep, that momentary interruption in the communication of the senses with external objects, may be defined the repose of the organs of sense and of voluntary motions. During sleep the interior or assimilating functions are carried on, digestion, absorption, circulation, respiration, the secretions and nutrition, are effected; some, as digestion, absorption, and nutrition, with more energy than when awake, while others are manifestly retarded. The pulse during sleep is slower and weaker, inspirations less frequent, insensible transpiration, urine, and all other humours from the blood, are secreted in smaller quantity; digestion, on the contrary, is very active, inhalation is equally augmented; hence the danger of sleeping in unhealthy air. It is a known fact that the marshy effluvia that render the country about Rome so insalubrious, almost infallibly occasion intermittent fevers if we pass the night there, while travellers who pass through without stopping are not at all affected.

The human body presents, with tolerable accuracy, the model of the centripetal and centrifugal powers of ancient philosophy. The motion of several of the systems that enter into its structure, is directed from the centre to the circumference; it is a true exhalation that expels the produce and continual destruction of organs; such is the action of the heart, arteries, and of all secretory glands. Other actions, on the contrary, are directed from the circumference towards the centre, and it is by these means that we continually receive, from the aliments introduced into the digestive organs, the air that penetrates the internal structure of the lungs and surrounds the surface of the body, the elements of its growth and reparation: these two motions in an opposite direction continually balance each other, and alternately preponderate according to age, sex, sleep, or waking. During sleep the motions are directed from the circumference towards the centre (*Motus in somno intrò vergunt*, Hippoc.); and if the organs that connect our intercourse with external objects repose, the internal parts act with greater advantage (*Somnus labor visceribus*, Hippoc.). A man about forty years of age, afflicted with a kind of imbecility, came a year and half ago to the hospital of the North for the cure of some scrofulous glands; during that long space of time he constantly remained in bed, sleeping five sixths of the day, tormented by hunger, and passing the short intervals of waking in satisfying his craving appetite: his digestion was always active and easy: he preserved his flesh notwithstanding muscular action was extremely languid, the pulse very slow and feeble. In this individual, who, to speak the language of Bordeu, existed under the empire of the stomach, moral affections were circumscribed in the desire of aliment and of repose: influenced by an insurmountable laziness, it required the greatest difficulty to make him take the least exercise.

Watching may be considered as a state of considerable effort and expenditure of the sensitive and moving principle by the organs of our sensations and motions: this principle would have soon been exhausted by an uninterrupted effusion, if its reparation were not facilitated by long intervals of rest. This interruption in the exercise of the senses and of voluntary motions presents a duration relative to that of their exercise. It has been already observed, that there are functions so essential to life, that their organs could only have short moments of repose; but that these intervals are so near together, that the time is found divided into two almost equal portions, one of which belongs to rest, the other to a state of activity. The functions that maintain our connexions with surrounding objects should be capable of persisting, during a certain time, in a state of continued activity; for it is very obvious how imperfect they would have been if interrupted every instant: their state of quiescence, which constitutes sleep, is equally protracted.

The duration of sleep is generally from one fourth to one third of the whole day; we seldom sleep less than six, or more than eight hours. Children, however, sleep more, and in proportion to their early infancy; elderly persons, on the contrary, enjoy only short and interrupted sleep. Grimaud remarks on this subject, that it is as if, according to the idea of Stahl, children could forebode that in the long career they have to maintain, there is sufficient time for them to contemplate at leisure the acts of life; and that old men, being near the termination of their existence, feel the necessity of seizing the enjoyment of a blessing that is about to escape from them.

> Carnivorous animals sleep longer than herbivorous, because they exert greater motion during the intervals of being awake; and perhaps also, because animal substances by which they are nourished, containing a greater number of nutritive particles in the same bulk, they require a shorter time to devour their aliment and provide for their subsistence.

If the sleep of the infant be so long, profound, and tranquil, that should be attributed to the very great activity of assimilating functions, and perhaps to the habitude of sleep, since the first nine months of existence had been passed in that state, or the whole time preceding its birth. In advanced age the internal functions languish, their organs do not arrest the attention of the principle of life; besides, the brain is so much surcharged with acquired ideas, that it is mostly awakened by them.

Sleep is a state essentially distinct from death, to which some authors have falsely connected it.

> To affirm that sleep is the image of death, that vegetables sleep continually, is to use expressions that are deficient in justice and exactness. How can plants which have neither brain nor nerves, which are destitute of organs of sense, of motions, and voice, enjoy sleep, that is merely a repose of organs of which they are completely deprived?

Sleep only suspends that portion of life, the design of which is to maintain a commerce with external objects necessary to our existence. It may be said that sleep and watching call for each other, and are of reciprocal necessity. The organs of sense and of motion, tired of acting, repose; but several circumstances favour this cessation of exertion.

If the organs of sense be continually excited, they will be kept in a constant state of watchfulness; the removal of the material causes of our sensations, therefore, has a tendency to plunge us into the embraces of sleep; on this account we enjoy it better during the silence and darkness of night; our organs successively fall into that state: the smell, feeling, and taste, are inactive even when the hearing and sight continue to transmit weak impressions. Confused perceptions terminate by disappearing; the internal senses cease to act as well as the muscles destined to perform voluntary motion, the action of which is entirely subordinate to that of the brain.

The texture of the eyelids is not so opake as to prevent us from distinguishing between light and darkness through their substance; for which reason, a light in the apartment prevents us from sleeping. On the same principle, the day which succeeds to night is a cause of waking, since the light can act on the globe of the eye notwithstanding the eyelids being closed.

Physiologists have endeavoured to assign a proximate cause of sleep. Some have affirmed that this state was occasioned by a collapse of the laminæ of the cerebellum, which, in their judgment, are different during watchfulness; and they support the doctrine by an experiment that consists in compressing the brain of a living animal to induce immediate sleep: this sleep, like that produced by the compression of any other part of the cerebral mass, is a state completely morbid; it is no more natural than apoplexy. Others, doubtless considering sleep to be analogous to this latter affection, make it depend on the conflux of humours towards the brain during watching. This organ, they say, compressed by the blood that obstructs the vessels, falls into a state of extreme repletion: this opinion is equally devoid of rational foundation as the preceding. So long as the humours are abundantly carried towards the cerebral organ, they maintain it in a state of excitement unfavourable to sleep. Is it not a known and admitted fact, that when attentively occupied with any idea, or greatly affected by any object whatever, we cannot enjoy the comforts of sleep? Coffee, spirituous liquors in small quantity, cause *insomnia*, by exciting the circulatory powers, by determining a more considerable afflux of blood towards the brain; on the contrary, every thing which can attract this fluid to another organ, as copious bleedings, foot-baths, purgatives, digestion, copulation, severe external cold, or whatever may serve to diminish the force with which it is propelled, as ebriety and general debility, have powerful influence over sleep; therefore it is observed that the brain falls into a state of collapse during its continuance, a proof that the quantity of blood carried to it is considerably diminished.

The organs of sense, which successively pass into sleep, have the same arrangement in the recovery of their powers; sound and light at first produce confused impressions on the eyes and ears; these sensations soon become more distinct; we begin to perceive odours, to distinguish tastes, and form a judgment of bodies by feeling: the organs of our motions prepare to enter into action, we then convey ourselves wherever volition may dictate. (See in the chapter on Motion, No. CXXIII.) The causes of waking act by determining a greater quantity of blood to the brain; they comprehend every thing that can stimulate the senses—thus the return of noise and light by the rising of the sun; they sometimes act internally—thus urine, excrements, and other liquors accumulated in various *receptacula*, irritate by their presence, and propagate towards the brain a sensation that concurs to dissipate sleep. Custom has the most remarkable influence over this phenomenon as over all actions that take place in the nervous and sensible system. Many persons enjoy repose amidst confused noise, which at first prevented them from obtaining it. A person who has a fixed and usual hour of awaking, does daily awake at that hour, whatever necessity he may have of sleeping longer: this act is also under the power of volition; in order to rouse at any given hour it is only necessary to will it with resolution.

Dreaming, Somnambulism.

CXVII. Although sleep implies the present repose of the organs of sensation and of motion, some of these organs may continue in their activity, which establishes intermediate states between sleep and waking, real mixed situations that have various degrees of relation to one or the other state. Let us suppose, for example, that the imagination may reproduce in the brain sensations which it has formerly experienced, the intellect labours, associates, and combines ideas dissimilar, although sometimes natural, produces strange and ridiculous monsters, causes us to feel joy, hope, sorrow, surprise or fear; and all these ideas, all these passions, represent themselves when we are awake, leave a remembrance more or less exact, which does not permit us to doubt but that the brain has, in reality, acted during the quiescence of the senses and organs of motion: the name of *dreams* has been given to these phenomena. Sometimes we speak when dreaming, and this state has a greater affinity to watching, since the action of the brain is joined to that of the voice and speech. In fact, all the relative functions may be exerted except the external senses. The brain merely acts and determines the action of the organs of motion of the voice and speech in consequence of anterior impressions; and this state, which only differs from sleep by the activity of the senses, is called *somnambulism*.

Surprising histories are recorded on this subject. Sleep-walkers have been known to rise, dress themselves, go out, carefully opening and shutting all the doors, dig in a garden, draw water from a well, maintain a rational and connected conversation, return to their rest, and then awake without preserving any remembrance of those things which they have done during sleep. This state is always very dangerous; for as they only conduct themselves agreeably to impressions received when awake, sleep-walkers are not guarded by their senses against things that threaten their existence, they cannot avoid any dangers that arise; it has been therefore found that they frequently precipitate themselves from the windows of their apartments, or fall from the roof of the house on which they had climbed, without being more able than others to remain in that situation, as believed by the vulgar, who are always great admirers of mysteries.

Sometimes an organ of sense remains open to impressions of bodies that affect it; the intellectual exertion may then be directed according to the will: in this manner persons who talk in their sleep are made to converse on different subjects, and their most secret thoughts are promulgated. This fact may be advanced as a proof of the errors of the senses, and of the necessity we have of correcting them by each other.

The disposition of organs influences the nature of things with which we are occupied during dreams; the superabundance of seminal fluid suggests venereal dreams; in pituitary cachexies patients dream of objects, the nature of which resembles that of their humours. On this principle dropsical persons see nothing but waters and fountains; while to the man labouring under an inflammatory affection all bodies appear of a red colour, that is, of the colour of blood, which is the predominant humour.

Difficult digestion troubles sleep. The stomach, too full of aliment, impedes the descent of the diaphragm; the thorax dilates with difficulty; the blood, which cannot pass through the lungs, stagnates in the right cavities of the heart, whence arises a distressing sensation; it seems as if a vast body loaded the chest, and is about to suffocate us; we suddenly awake to withdraw ourselves from such a pressing danger: this is what is called *incubus*, or the nightmare, an affection that may arise from other causes, an hydro-thorax, for example, but which depends on a difficult passage of blood through the lungs.

The human species is not the only race of beings that suffer these kinds of agitations during sleep, which are in general comprehended under the denomination of dreams: these phenomena are likewise observed in animals, which are more influenced by them in proportion to their greater irritability. The dog and the horse dream more than other ruminating animals; the former barks, the latter sometimes neighs during sleep. Cows that give suck express their solicitude by obscure lowings; the bull and ram seem tormented with desires, which they chiefly express by a motion of their lips.

After what has been said on sleep and dreams, it will not be difficult to explain why the first so little restores strength, when we are distracted by frightful dreams: we sometimes awake extremely fatigued with the uneasiness and motions undergone by endeavouring to avoid imaginary dangers.

Sympathies.

CXVIII. There exist between all the parts of the living body certain relative connexions; all maintain a correspondence and reciprocal commerce of sentiments and affections. These bonds, which unite together all the organs by establishing a surprising concord, a perfect harmony between all actions performed in the animal machine, are known by the name of *sympathies*. We are still unacquainted with the nature of this phenomenon; we do not know why, when one part is irritated, another very distant part should perceive this irritation, and even contract; nor are we agreed on the peculiar instruments of sympathy, that is, of the organs that connect together two parts, one of which perceives or acts while the other is affected.

Whytt has clearly demonstrated that the nerves could not be considered the exclusive means of it, since several muscles of a limb that receive twigs from the same nerve do not sympathize together, while there may exist a close and manifest intercourse between two parts, the nerves of which have no immediate connexion, since each nervous filament having two extremities, one in the brain, the other at the part of its distribution, remains free from those of the same trunk, and does not communicate with them, &c.

We may distinguish different species of sympathy: 1st, Two organs that perform the same function, the kidneys, for example, are reciprocally influenced; the impregnated uterus causes both breasts to participate in its own state, and to receive a supply of humours necessary for the secretion that is about to take place, &c. 2d, The continuity of membranes is a powerful medium of sympathy. The presence of worms in the intestinal canal occasions a troublesome *pruritus* about the nostrils. In calculous affections of the bladder, patients experience a greater or less degree of itching at the extremity of the glans penis. 3d, The irritation of a part causes the secretion of a fluid: on this principle the presence of food in the mouth in contact with the extremity of the Stenonian, or the excretory duct of the parotid gland, produces an irritation that is propagated as far as the glands, and augments their secretion. 4th, If we irritate the pituitary membrane, the diaphragm, which has no immediate organic connexion with it, either nervous, vascular, or membranous, contracts, and we sneeze. Should not this sympathy be classed among those which Haller makes dependent on the reaction of the *sensorium commune?* If the sensation produced by snuff on the olfactory nerves be too acute, it is transmitted to the brain, which determines to the diaphragm a sufficient degree of the principle of motion to induce a sudden contraction of the diameters of the chest, and expel a volume of air sufficient to detach from the surface of the nostrils those bodies which had been the cause of the disagreeable affection. 5th, Does not the principle of life seem to direct sympathetic phenomena? The rectum, when irritated by the presence of excrements, contracts. What induces the auxiliary and simultaneous action of the diaphragm and abdominal muscles? is it in consequence of organic connexions? why, also, is not the sympathy reciprocal? for what reason does not the rectum contract when the diaphragm is irritated? is it possible for the reiterated habit of the same motions to explain the harmony observed in the action of symmetrical organs? when we direct our sight to an object situated laterally, why does the rectus externus muscle of one eye act at the same instant as the rectus internus of the other? the indispensable utility of this phenomenon is evidently perceived for the parallelism of visual axes; but can any cause be assigned for it? for what reason is it so difficult to perform rotatory motions in a contrary direction with two members situated in the same lateral division of the body? If we conclude with Rega, that there are sympathies of action or *irritability* (*consensus actionum*), sympathies of *sensibility* (*consensus passionum*), &c. does it convey to us any just idea of the innumerable varieties of this phenomenon, and of its frequent anomalies?

All these difficulties induce us to excuse Whytt for having considered the soul as the only cause of sympathies, which was a modest avowal of the impossibility of explaining them. We cannot regard sympathies as anomalous acts, as aberrations from vital properties. Is the natural order of sensibility and irritability destroyed by the sympathetic erection of the clitoris and nipple, or by the swelling of the breast, occasioned in consequence of distention of the uterus?

It is by means of sympathies that all the organs concur to one and the same end, and mutually assist each other; it is by them that we can explain how a local affection, at first topical and circumscribed, is propagated throughout every system; for it is in this manner that a morbid state is established; it is always from the isolated affection of one organ, or one system of organs, that those diseases called general take their origin by *association.*

The knowledge of sympathies is of the greatest utility in the practice of physic.

> This knowledge may be acquired from the works of the ancients, and particularly Hippocrates, who seems to have understood the importance of this subject: among the moderns Van Helmont, Baglivi, Rega, Whytt, Hunter, and Barthez, have collected a great number of facts on this subject, taken from experiments on animals, and particularly from the observation of diseases.

When we wish to remove the irritation fixed on a diseased organ, revulsive remedies are best applied to that part which observation and experience have proved to be more intimately acted on by sympathetic connexions.

This should, perhaps, be the place to examine the nature of those concealed relations which bring together men, and of those discongruities which separate them; the causes of those secret impulses that propel two beings towards each other, and oblige them to yield to an irresistible *penchant;* to make researches on the reason of antipathy; and, in fact, to establish the entire theory of sentiments and moral affections. Such an enterprise, independently of being beyond our ability to perform, has not a direct relation to our subject; it would require considerable time, and whoever might attempt it would be continually liable to lose himself in the vast field of conjectures.

On Habit.

CXIX. It is much easier to appreciate the influence of this expression than to define it; we may say, however, that it consists in the reiterated repetition of certain acts, of certain motions, in which all the body or only some of its parts participate. The most remarkable effect of habit is ultimately to diminish the sensibility of organs: thus a catheter introduced into the bladder, and suffered to remain in the urethra, the first day causes severe pain, the second day its presence is supportable, the third it is merely inconvenient, and the fourth it is hardly pereeived. The use of snuff at first augments the quantity of nasal mucus; but after being continued a certain time it ceases to affect the pituitary membrane, and the secretion would experience considerable diminution if the quantity of that irritating powder were not increased. The presence of a canula in the nasal duct after the operation for *fistula lachrymalis*, at first augments the mucous secretion of that passage; but the secretion regains its natural state in proportion as the parts become accustomed to the extraneous body, &c.

It is only by our sensations that we are informed of our existence. The whole of life, to express ourselves in the systematic and figurative language of a modern author, consists in the action of stimulants on the vital powers (*Tota* *vita quanta est, consistit in stimulo et vi vitali*, Brown). A continual deficiency of emotions torments all sensible beings; all their actions tend to procure for themselves sensations that are agreeable or disagreeable; for, in defect of other sentiments, pain is sometimes an acquisition. Those who have worn out all their modes of enjoyment, and tasted every pleasure, are carried to suicide by a disgust of life: is it then possible to live when we are no longer capable of perceiving?

The habit of suffering renders us, at last, insensible to pain; but every thing in this world counterbalances itself, and if habit alleviate our sufferings by blunting sensibility, it equally diminishes the source of our dearest enjoyments. Pleasure and pain, those extremes of sensations, in some degree approximate and become indifferent to those who have contracted a long habitude of them: thence arises inconstancy, or rather the insatiable desire of varying the object of our pursuits; that imperious necessity of new emotions which causes us to taste with insipidity those felicities which we pursue with such ardour and constancy, and which induces us to abandon those charms by which we were captivated.

If we require a striking example of the powerful influence of habit over the action of organs, it may be illustrated in the criminal, who, according to Sanctorius, fell sick when taken out of an infected dungeon, and did not recover until he had been returned into the impure air to which he had been so long habituated. Mithridates, that king of Pontus so formidable to the Romans, whose power he long kept at defiance, when afflicted by the fear of falling alive into the hands of his enemies, could not destroy himself by taking large doses of the most active poisons, because he had so long accustomed himself to their use.

In some rare instances, habit produces a contrary effect. Cullen remarks that he has seen persons so habituated to make themselves vomit, that their stomach only required the twentieth part of a grain of tartar emetic to produce that convulsive action.

We have not, therefore, presumed too much by saying of habit that it is a second nature, the laws of which ought to be respected.

The sexual parts of females, on account of their active sensibility, are, in a very marked and peculiar manner, subject to the powerful influence of habit. The uterus that has prematurely expelled a fœtus, preserves a kind of propensity to perform the same act when arrived at an equal period of gravidity; therefore we should redouble our efforts to prevent abortion in those women who are subject to it during the month in which this accident has happened.

May not death be admitted as a natural consequence of the laws of sensibility? Life, dependent on the continual excitement of the *living solid* by the fluids that are conveyed to it, ceases; because, after being accustomed to the impressions that these liquids produce on them, irritable and sensible parts become, at last, no longer able to perceive them: their action gradually destroyed would, perhaps, revive if the stimulating powers were to acquire additional energy.

The knowledge of the power of habit is particularly elucidated in the application of remedies, which generally operate in the cure of diseases only by modifying sensibility. A wound in which dry lint would keep up a degree of inflammation necessary to effect a cicatrix, becomes insensible to this application; granulations are luxuriant and soft, the surface becomes worse: the lint should then be sprinkled with some irritating powder, or moistened with a stimulating liquid. The doses of a medicine long continued may be increased with impunity: on this principle the quantity of mercurial medicines is gradually increased in the treatment of the venereal disease. *Hoffman*, for this reason, advsies us in the treatment of chronic diseases, to suspend the administration of remedies at intervals, and afterwards to resume them, lest the system should become habituated to them, and ultimately be insensible to their influence: the same motive, should induce us to vary medicines, and to employ in succession all those which have nearly the same virtues; for each of them affects sensibility in its own peculiar manner. The nervous system, therefore, may be compared to a soil, rich in different juices, and which requires the cultivator to plant the germs of a diversified vegetation to develop the whole of its fecundity.

CHAPTER VIII.

MOTION.

In this chapter the motions performed by the muscles under the influence of volition are alone considered: and the motions of *locomotion*, by the assistance of which our body is removed and carried from one place to another, avoids or receives the approach of surrounding beings, attracts, embraces, or repels them. Interior, involuntary, organic motions, by the assistance of which each function is performed, have been separately investigated.

CXX. THE organs of our motions may be distinguished into *active* and *passive:* the first are the muscles, the second the bones, and all the parts that are concerned in their articulations. In fact, when, from impressions received by the organs of sense, we wish to approach towards or remove from the object that produced it, the muscular organs, stimulated by cerebral influx, contract; while the bones that obey this action only perform a secondary part, passive, and may be considered as levers absolutely inert.

The muscles are fibrous fasciculi, always more or less red in man, although this colour is not essential, since it may be destroyed, and the muscular texture rendered white by maceration, or repeated affusion of water.

Whatever may be the situation, length, breadth, thickness, figure, or direction of a muscle, it is composed by the assemblage of several fasciculi of fibres enveloped in cellular sheaths, like that which covers the body of the muscle itself, and distinguishes it from surrounding parts. Each fasciculus is formed by the union of a multitude of fibres, so minute that our anatomical instruments cannot completely subdivide them; and the smallest perceptible fibre consists in the juxtaposition of several fibrils of indefinable tenuity. As the ultimate divisions of the muscular fibre completely elude our means of research, it would be absurd to endeavour to explain its minute structure, and, like *Muys*, to write a long dissertation on this obscure point of physiology. Shall we conclude, with the author just quoted, that each perceptible fibre is formed by three fibrils, the thickness of which is in progressive decrease; and with Lewenhoëk, that the diameter of this elementary fibre is only the hundred thousandth part of that of a grain of sand; with Swammerdam, de Heyde, Cowper, Ruysch, and Borelli, that this primitive fibre is composed of globular, rhomboidal, or nodous moleculæ; with Le Cat, that its nature is absolutely nervous; with Wieussens and Willis, that it is only the ultimate ramifications of arteries; with others, that it is cellular, tomentous, &c.? To explain the phenomena of muscular action, it is sufficient to consider each fibre as formed by a series of moleculæ of a particular nature, united together by a medium unknown; whether this be gluten, adeps, or any other substance; and that the cohesion, the mutual adhesion of these moleculæ is manifestly kept up by the vital power, since in dead subjects the muscles are lacerated by efforts against which they would have resisted during life; and in this latter state, the resistance is so great that nothing is more uncommon than a rupture of their substance.

These fibres, which possess in so great a degree the property of becoming shorter, and of contracting when irritated, whatever state of fineness or tenuity they may have, receive nerves and vessels. In fact, though their nature be neither nervous nor vascular, of which we may be easily convinced by comparing the volume of vessels and nerves that enter into the structure of muscles with those of other organs, and by reflecting on the difference of their properties; each fibre has a power of contracting itself on the blood conveyed to them by arteries, and on the fluid carried from the brain by the means of nerves. A cellular sheath surrounds these fibrils (and perhaps the nerves and vessels terminate in its structure), others unite them together; they are again separated by coverings into fasciculi: these united in the same manner form larger or smaller packets, and from the assemblage of the latter result the body of muscles. Fat is seldom collected in the cellular structure that maintains a union between the smallest fasciculi: it is accumulated in a small quantity in the interstices of more considerable packets; but it is more abundant surrounding the muscle itself. A lymphatic and aqueous vapour fills these little cells, maintains the flexibility of the texture, and favours the action of the organ, which a more viscid humour would have impeded.

The generality of muscles terminate in rounded bodies of a shining whiteness, partaking of the red colour of muscle, into the substance of which one of the extremities extends, while the other extremity is attached to bones, and seems to be confounded with the periosteum covering them, though these *tendons* (a name given to those bodies in which muscles terminate) are perfectly distinct from it. The tendons are formed by an assemblage of longitudinal and parallel fibres; their structure is more compact than that of muscles; they are harder, and neither visibly receive nerves nor apparent vessels: they consequently have only a weak degree of life, and therefore often rupture by the contractile efforts of the muscles. Muscular fibres are attached to the surface of tendinous parts without being continued with the filaments forming the latter; they are arranged in a different manner, and are inserted by angles more or less obtuse.

Tendons, by penetrating into the fleshy body of muscles, expand, diminish in thickness, and constitute internal aponeuroses. External aponeuroses, independent of tendons, although their structure be alike, and only differ in the component fibres forming thin broad expansions, sometimes are reflected over a portion of the muscle to which they belong, in other cases they surround the whole limb, afford points of attachment to various muscles that constitute it, prevent these muscles and their tendinous extremities from altering their situation, have some influence in directing their action, and increase their power in the same manner as a belt moderately tightened augments the vigour of a wrestler.

CXXI. When a muscle contracts, its fibres become wrinkled across, their extremities approximate, then separate, and again approach each other. A less agitation succeeds to these undulatory oscillations, which are very rapid; the body of the muscle, swelled, indurated by becoming shorter, has exerted an effort of traction over the tendon in which it terminates; the bone to which the latter is attached has been moved, if other powers greater than the acting muscle have not prevented it from obeying this action. Although the muscles evidently swell in contracting, and the members to which they belong are more confined by ligatures that had been passed round them; yet the total volume of the contractile organ diminishes; it loses more in length than it acquires in circumference: this is proved by Glisson's experiment, made by immersing the arm in a vessel filled with a liquid, the level of which sinks when the muscles are brought into action. The diminution of volume, however, cannot be calculated by the degree of depression in the liquid, since this effect is to be partly attributed to the compression of adipose membrane in the interstices of muscles.

The perfect state of the vessels and nerves distributed to muscles is an indispensable condition of their contraction; they may be rendered completely paralytic by preventing the afflux of blood or nervous fluid, by making a ligature on the arteries or nerves, or preventing the return of blood through the veins towards the heart. The section or ligature of nerves suddenly prevents the action of muscles to which they are distributed: the interception of the course of arterial blood produces the same effect, though in a less prompt and instantaneous manner; and it is very remarkable that the integrity of veins is as essential to muscular action as that of arteries. Kaau-Boërhaave has proved that the ligature of the vena cava above the origin of the iliacs occasioned a loss of motion in the posterior extremities, as well as tying the aorta, agreeably to Steno's mode, at the same distance. This is an additional proof of what we have advanced in another part of the work, of the stupefactive property of the blood that flows in the veins.

The irritability of muscles destined to perform voluntary motions, is in a direct ratio of the number and magnitude of the nerves and arteries distributed in their structure. The tongue, which of all other contractile organs receives the greatest supply of cerebral nerves, is also that of all others subject to the influence of volition, which possesses the most extensive, free, and varied motions. The muscles of the larynx, the intercostals, receive almost as much, if the smallness of these parts be duly considered, &c.

It is not necessary to repeat that we are not here speaking of the motions that are more or less involuntary, performed by muscles which receive their nerves in part, or totally, from the great sympathetics. Although the particular nature of these nerves may have great influence over the faculties of the organs in the texture of which they are distributed, yet we find that the general rule suffers few exceptions, since the heart and diaphragm, organs that hold the first rank among irritable parts, receive a very liberal portion of vessels and nerves.

CXXII. Among the various hypotheses fabricated to explain the phenomena of muscular contraction, that which makes it dependent on combinations of hydrogen, carbon, azot, and other combustible substances found in the fleshy body of the muscle, with the oxygen conveyed by arterial blood, seems to me not only the most ingenious, but also that which embraces the greatest number of probabilities.

In order for this combination to take effect, it is not only necessary for the arterial blood to supply the muscular structure, and for the oxygen to come into contact with the substances it is to oxydate, but a nervous influence must pass through the texture of the muscle to determine the decompositions that take place, as the passage of the electric spark gives origin to water by the combination of two gases from which it is formed. According to this theory, invented by Girtanner, all the changes effected in a muscle that contracts, the swelling, shortening, induration of its structure, and the change of temperature, ought to be attributed to this reciprocal action of the elements of the muscular fibre, and the oxydation of arterial blood.

Muscular flesh is harder, more compact, and of a darker colour in proportion to the excess of motion in the animal: it is evident what difference exists between the flesh of deer and that of domestic animals; between tame and wild fowl: it is equally white, soft, tender, and delicate in one, as it is hard, fibrous, tough, dark, and strong smelling in the other. Respiration, the principal use of which is to impregnate arterial blood with the oxygen necessary for the contractions of the muscular fibre, is by so much more complete, and alters a greater quantity of atmospheric air, in proportion as animals are destined by nature to perform greater motions: those birds also which are obliged to support themselves in the air by rapid and strong exertions, have a more considerable share of respiration. Wrestlers, who astonish us by the development of their muscular organs, and the vast efforts of which they are capable, have a very large thorax, a strong voice, and capacious lungs.

I never saw a very strong man who had not broad shoulders, which indicates a great extent of the cavity of respiration: if there be individuals who seem to deviate from this general law, it is because they have augmented the natural power of their muscles by frequent exercise and a laborious life. This increase is seldom universal, but mostly confined to certain parts that have been more particularly exerted: the arms, legs, or shoulders.

Persons that run consume a great quantity of the principle of motion, and are accustomed to *pant*, that is, to breathe with unusual rapidity, in order to oxydate as much as possible the blood which is to maintain the contractions necessary for running.

The Preponderance of the Flexor over the Extensor Muscles.

CXXIII. The extensor muscles are generally weaker than the flexors: thus the most natural situation, that in which all the powers maintain a just equilibrium; that which our members take during sleep, when volition ceases to determine the vital influx to the muscles subject to its influence; that which we preserve the longest time without fatigue, is a middle state between flexion and extension, a true semi-flexion.

The theory of the preponderance of the flexor over the extensor muscles belongs to me exclusively; I first promulgated it in the collection of Memoirs of the Medical Society of Paris for the 7th year of the republic (1799).

We have endeavoured to investigate the causes of this preponderance of the flexors over their antagonists. According to Borelli, the flexors of the same articulation being shorter than the extensors, when both equally contract, the former should make the limb perform a greater range of motion, and detain it on that side (*Musculi flexores ejusdem articuli breviores sunt extensoribus, et utrique æque contrahuntur.* Prop. 130, *de Motu Animalium.*) But, independently of its not being correct, that the flexors are shorter than the extensors, if we estimate the extent of motions that a muscle can perform by its length, we should neither measure the whole length of the fleshy body of the muscle, nor include its tendinous extremity, but consider the particular length of the fibres that compose it, and on which totally depend the extent of the motions performed by its contraction.

The degree of shortening of which a muscle is susceptible is always in proportion to the length of its fleshy fibres, as the force with which it contracts is in a direct ratio with their number; therefore, if the fibres of the flexors be more numerous than those of the extensors, it follows as a necessary consequence that the member will be kept in a state of flexion, when the principle of motion is equally distributed; and although the number of fibres be equal in the flexors and extensors, the extremities would be still in a bent position if the fibres of the former were longer, and thus cause them to perform a greater range of action.

If we examine the different regions of the body, the articulation of the limbs, particularly that of the knee, the knowledge of which is the most important to comprehend the theory of standing, we shall find the flexor muscles greatly exceed the extensors, both in the number and length of their fleshy fibres. If we compare the biceps cruris, semi-tendinosus, semi-membranosus, gracilis, sartorius, gastrocnemii, plantaris, and popliteus, all of which concur to produce the flexion of the leg on the thigh, with the triceps cruris, and the rectus, which effect extension, it will be soon perceived that the fibres of the latter are much shorter and less numerous. Those of the sartorius and gracilis are the longest of all muscles employed in voluntary motions: the fibres of the posterior muscles of the extremity are not shorter than those of the anterior muscles.

On the other hand, the flexor muscles are inserted into bones which they are to act upon at a greater distance from the centre of motion: in fact, if the insertion of the semi-membranosus be at the same height, the sartorius, gracilis, semi-tendinosus, biceps, and popliteus, are attached lower than the extensors of the leg. But this difference is more particularly marked with respect to the fine plantaris and gastrocnemii, which terminate as far as possible from the centre of motions, and act by a lever of considerable length: the greater number of these muscles, indeed, separate much more than the extensors from a parallelism with the bones of the leg. It is observed that the curvatures made by the three muscles, sartorius, gracilis, and semi-tendinosus, render the angle of their insertion into the leg more advantageous.

In this point of view the gastrocnemii muscles may be compared to the supinator longus, the use of which is not merely to effect supination of the hand, as mentioned by Heister, but also to bend the fore-arm on the arm with a power greater in proportion as its attachment is at a more considerable distance from the articulation of the elbow, and from its fibres being the longest of any of the muscles of the superior extremity.

The flexor muscles, almost parallel to the levers which they are to affect, from the instant of entering into action, tend to become perpendicular to them in proportion as the motion of flexion is performed. Thus the brachialis, biceps, supinator longus, of which the small line of direction is almost parallel to that of the bones of the fore-arm, become oblique when the flexion of this part commences, then perpendicular to the bone, and terminate by forming angles the most efficient for their action. The flexors of the leg are situated in a similar manner; the angle of their insertion is enlarged in proportion as the limb is bent on the thigh; the extensor muscles, on the contrary, are in the most advantageous position when they begin to contract; as extension advances, they tend to become parallel to the levers on which they act; their action is even neutralized before the parallelism is exact: at the elbow, in consequence of the resistance from the olecranon; at the knee, by numerous ligaments and the tendons situated towards the posterior part of the articulation.

The flexor muscles, therefore, have longer and more numerous fibres than the extensors; their insertion into bones is farther from the centre of their motions, under an angle more open, and which increases in proportion as the limbs are in a state of flexion: it is to these causes united that the flexors are indebted for the superiority they possess; and the disposition of articular surfaces, which are mostly inclined towards the side of flexure, is to be attributed to the great extent of motion effected by these muscles.

This preponderance of the flexor muscles varies according to the periods of age. In the fœtus all parts are reflected on themselves without proportion. This convolution of the new individual on itself may be perceived from the time of early gestation, when it resembles a French bean, suspended by the umbilical chord in the midst of the liquor of the amnion: the embryo floats in a cavity where it becomes progressively more confined as it advances towards the time of birth. This extraordinary flexion of parts, necessary for the product of conception, accommodates itself to the elliptical form of the uterus, and concurs to afford the muscles that effect it the superiority which they maintain during the remainder of life.

The new-born infant preserves in a remarkable manner the habits of gestation, but as it advances in growth it becomes less curved: frequent pandiculations or stretchings denote the endeavour to establish a just proportion between the muscular powers. When the infant is able to stand erect and left to itself, all its parts are in a state of semi-flexion, its walk tottering, continually pressing towards the point of support. But in middle life the preponderance of the flexors over the extensors becomes less apparent; man possesses the full and entire exercise of his locomotive faculties, but as he advances in age this vigour abandons him; the extensor muscles gradually return to that state of relative debility in which they were during infancy, and become incapable of completing the action of standing in a firm and durable manner.

The state of our limbs during sleep resembles that of the fœtus, which, according to Buffon's remarks, may be considered in a sound sleep: its cessation in man, as well as the generality of animals, is followed by frequent pandiculations. We stretch the limbs to restore to the extensors a degree of tone necessary for the functions that they are to perform when awake. Barthez refers the crowing and fluttering of wings, by which the cock announces his waking, to a similar purpose.

Haller is of opinion that these extensions have for their object the removal of that uneasy sensation produced by protracted flexion. " *Nunc quidem homines et animalia, extendunt artus, quod iis ferè conflexis dormiant, et ex eo perpetuo situ in musculis sensus* *incommodus oriatur, quem extensione tollunt."*—(*Phænomena expergiscentium, Elementa Physiologiæ*, tom. v. p. 621.)

It may happen that parts continue in a state of extension during sleep from an improper direction of vital influx; Hippocrates, on this account, recommends us carefully to observe the limbs when asleep, and remarks, that the more deviation there is from the natural state, so much the greater danger of life. In certain nervous diseases, characterized by a manifest aberration in the distribution of vital powers, long-continued extension should be considered an unfavourable omen. I have several times had occasion to observe, that, in wounds complicated with convulsions and tetanus, these terrible accidents are manifested by a persevering extension of the limbs during sleep, before any difficulty of motion in the inferior maxilla has happened.

Diseases and every kind of excess occasion a remarkable debility in the extensor muscles; we therefore see convalescents, and those who have been addicted to excess of venery, walk with their knees so much the more bent, as the weakness is greater, and the power of the extensor muscles more radically enervated. The flexion of the knee has to act on that state in which the tendons of the extensors of the leg meet the tibia, under an angle, the extent of which compensates for the diminution of their energy.

The Power of Muscles; the Method of estimating it; the Deductions experienced.

CXXIV. The real power of muscles is immense; it seems to increase in the ratio of resistances opposed to it, and never can be estimated with precision. Borelli was guilty of great errors in rating the power of a muscle according to its weight compared to that of another muscle; for cellular membrane, adeps, tendinous and aponeurotic parts, may increase their bulk without augmenting their power. This property is always relative to the number of fleshy fibres that enter into their composition; nature, therefore, has multiplied these fibres in muscles that have to overcome powerful resistances; and to prevent this increase from giving the limbs too much bulk, they are rendered shorter by approximating their points of insertion, which are always on extensive surfaces, whether aponeurotic or osseous. We may, in general, form a judgment of the power of a muscle by the extent of surface to which its fleshy fibres are attached; thus the gastrocnemii and soleus have short, compact fibres, running obliquely between two large aponeuroses.

If the force with which a muscle contracts is in a direct ratio to the number of its fibres, the degree of contraction of which it is susceptible, and consequently the extent of motions that it can effect on the limb, is relative to the length of the same fibres: thus the sartorius, which has the longest fibres of any muscle in the body, possesses the most extensive contraction, and performs the most considerable motion of the leg. The precise limits of contraction in each particular muscular fibre cannot be assigned; for though the generality of the long muscles of the extremities only diminish a third of their length in contraction, the circular fibres of the stomach, which, in the state of extreme dilatation of this organ, form circles of near a foot in diameter, can contract themselves to such a degree when it has remained long empty, as to form a ring that is only one inch in circumference. In these cases of extreme elongation and constriction, is it the moleculæ, a series of which forms the muscular fibril, or the substance constituting the bond of union, that undergoes the change? or do both, at the same time, participate in the alteration?

Whatever may be the power of muscles, a great part of this power is rendered useless by the unfavourable disposition of the organs of our motions. The muscular powers, mostly parallel to the bones which they have to move, act less efficaciously on these levers in proportion as the small line of their direction is more remote from the perpendicular, and approaches the parallelism with them.

Besides, the generality of muscles are attached to bones near their articulations or centre of motion, and act upon them as levers of the third degree, that is, they are situated between the fulcrum and resistance; by thus multiplying levers of the third kind in the animal machine, nature has diminished force and augmented celerity; for in this kind of lever, the power need only go through a small space to induce the resistance to make a large sweep; besides, the fleshy fibres, in contracting, do not exert a direct traction on the tendon in which the muscle terminates; the fibres are mostly inserted obliquely into the aponeurotic expansion formed by the tendinous chord passing into the substance of the fleshy body; their action, therefore, agreeably to this line more or less oblique, is decomposed, and the only part usefully employed is that which is exerted in the direction of the tendon. The muscles often pass over several articulations to reach the bones which are to be moved; a portion of their force is lost in the action of the various parts in which the bone rests that is to receive the insertion: all these organic imperfections occasion a vast deduction of power, and render the greater part of it inefficient. It has been calculated that the deltoid muscle exerts a force equal to 2568 pounds, to surmount a resistance of 50 pounds; yet we are not to imagine that there is a loss of 2518; for the deltoid, acting upon the shoulder and arm, employs nearly the half of this force on each of those parts. This has induced the presumption, that, to estimate the entire power of a muscle, we should double the effect of its contraction, as its action passes at the same time both to the weight to be raised, or resistance to be overcome, and to the *fixed point*, to which its opposite extremity is attached.

If the muscles were exactly parallel to the bones, they could not move them in any sense; nature, therefore, has corrected the parallelism as much as possible, as we shall see in the bony system, by separating the tendons of the smaller line of direction of the bones, and by augmenting the angles under which they are inserted, whether situated in the passage of bones which alter their direction, as in the rotula and all the sesamoid bones; or, to produce the same effect, she may have made the articulating extremities of bones larger than their centre, or formed pullies on which the tendons or muscles themselves are reflected, as in the palate, obturatores interni, &c.

Nature, therefore, has not so much neglected mechanical advantages as might have been considered from a superficial examination of the organs of motion; and if we reflect, that, in different conditions of life, we have less occasion for force than agility, that force could be augmented by the multiplication of fibres, while to acquire celerity no means but the mechanical application of various kinds of levers could be used; and that it was necessary for the muscles to cover the bones to constitute the most advantageous form of our limbs; it will be admitted that nature, by frequently sacrificing force to celerity, has conciliated as much as possible these discordant powers.

That which is called a fixed point in the action of muscular organs does not always deserve that name; therefore, although it may be justly said that the generality of muscles of the thigh have their fixed point in the bones of the pelvis, to which their superior extremities are attached, and that they move the femur on the bones of the ilium, which are less movable than they; yet when the thigh is fixed by the action of other muscles, these move the pelvis on the thigh, and their fixed point becomes movable. The same principle exists with respect to all the muscles of the body; so that the fixed point is only that which in the greater number of cases constitutes the support of muscular action. This necessary fixed state of the bones, to which is attached one of the extremities of a muscle that we wish to contract, causes the smallest motion to require the action of several muscles, and indicates a complicated mechanism.

If the two opposite points to which the extremities of a muscle are attached be equally movable, contraction approximates them towards each other by passing through equal spaces, which would be unequal if their mobility were different. Each muscle has its antagonist, that is another muscle, the action of which is directly opposed to it: thus the action of the flexors counterpoises the action of the extensors; the adductors perform motions in directions opposite to the abductors. When two antagonist muscles act at the same time on a part equally movable in every sense, the powers thus opposed reciprocally destroy each other, and the part remains at rest; if we contract them in different degrees, the part is directed towards the muscle that had the strongest contractile force. If the antagonist be not direct, it follows a middle direction between that of the two moving powers: thus the rectus externus muscle of the eye is not the antagonist of the rectus inferior; therefore, when these muscles are contracted together, the eye is neither carried downwards nor outwards, but downwards and outwards at the same time; it is then said to move according to the diagonal of a parallelogram, the sides of which are formed by the two acting muscles.

The Nature of muscular Flesh.

CXXV. We shall not here treat on the manner in which the muscles receive nourishment, by retaining in the laminæ of their texture the fibrine carried to them in such abundance by the blood, that several, both among the ancients and moderns, have named this fluid liquid flesh; an expression both energetic and true, since all the organs are restored and receive growth by the change of its different parts into solids. Haller was the first who observed that the generality of muscular arteries are curved on themselves in a remarkable manner when penetrating into the muscles. This disposition, which should considerably retard the course of the blood, favours the formation and secretion of the elementary fibrine, which the muscle takes to appropriate to its own substance, and with which it has already a manifest conformity.

The chemical nature of muscle is nearly the same as the fibrine of the blood.

> Nothing better proves the essential differences that exist between the fleshy portion of muscles and their tendinous and aponeurotic parts, than the chemical analysis of these organs. Tendons and aponeuroses are completely dissolved into gelatine by long boiling, which, on the contrary, renders muscular flesh dry, by laying bare the fibrine, in consequence of the friction of the adeps in the cellular membrane, and of the albuminous juices in which it is enveloped.

Like the fibrine of the blood, muscle contains a quantity of azot, and is consequently very much animalized and highly putrescent. It is from muscular flesh that Bertholet has obtained, in a great proportion, the acid peculiar to animals, which this chemist has called the zoonic acid.

Galvanism.

CXXVI. A professor of anatomy in the university of Bologna was one day making experiments on electricity. In his elaboratory, near the machine, were some frogs that had been flayed, the limbs of which became convulsed every time a spark was drawn from the apparatus. Galvani, surprised at this phenomenon, made it a subject of investigation, and discovered that metals applied to the nerves and muscles of these animals occasioned powerful and sudden contractions when disposed in a certain manner. He gave the name of animal electricity to this order of new phenomena, from the analogy that he considered existing between these effects and those produced by electricity. This discovery was announced; several learned men, particularly in Italy, among whom we find Volta, became anxious to make additions to the labours of the inventor. The Medical Society at Edinburgh thought it would be useful to make this point of physiology the subject of one of their annual prizes, and signalized the work of Professor Crève, of Mayence, in which the term metallic irritation (irritamentum metallorum) is substituted for that of animal electricity. This new denomination is essentially false, since it tends to occasion a belief that irritation by metals can alone produce galvanic phenomena, while carbon, water, and many other substances can also effect them. The name animal electricity has also been superseded, notwithstanding the great analogy that exists between the effects of electricity and of *galvanism*, in favour of the latter term, which is not only applicable to the generality of the phenomena, but likewise serves to perpetuate the memory of the discoverer.

In order to give rise to galvanic effects, it is necessary to establish a communication between two points of one series of nervous and muscular organs. In this manner a *circle* is formed, one *arch* of which consists of the animal parts rendered the subject of experiment, while the other arch is composed of *excitatory* instruments, which generally consist of several pieces, some placed under the animal parts called *supporters;* others, destined to establish a communication between the latter, are called *communicators.*

To form a complete galvanic circle, take the thigh of a frog deprived of its skin, detach the crural nerve as far as the knee, put it on a piece of zinc; put the muscles of the leg on a piece of silver, then finish the excitatory arch, and complete the galvanic circle by establishing a communication between the two supporters by means of iron or copper wire, pewter or lead: the instant that the communicator touches the two supporters, a part of the *animal arch*, formed by the muscles of the leg will be convulsed. Although this disposition of the animal parts and of galvanic instruments be most favourable to the development of the phenomena, yet the composition of the animal and excitatory arcs may be much varied: thus, contractions are obtained by placing the two supporters under the nerve, and leaving the muscles out of the galvanic circle, which proves that nerves essentially constitute the animal arch.

It is not necessary for nerves to be entire in order to produce contractions; they take place whether the organs have been tied or cut through, provided there exist a simple contiguity between the divided ends. This proves that we cannot strictly conclude what happens in muscular action from that which takes place in galvanic phenomena; since, if a nerve be tied or divided, the muscles on which it is distributed lose the power of motion: however, I have observed that by disorganizing the nerve which constitutes the whole, or a part of the animal arch, by a strong contusion, the galvanic influence is interrupted, or at least much impeded.

The cuticle is an obstacle to galvanic effects; they are always feebly manifested in parts covered by it: when it is moist, fine, and delicate, the effect is not entirely interrupted, hence the possibility of making the following experiments on ourselves.

Place a plate of zinc under the tongue, put a flat piece of silver on its superior surface; make them touch each other, and you will perceive an acerb taste accompanied with a slight trembling. Apply two pieces of different metals to the eyes, then make a communication between them, and you will perceive sparks. Put a small piece of silver into the mouth, introduce a piece of pewter, copper, or any other metal into the anus, make a communication between them with a piece of iron wire; the long, hollow muscle extending from the mouth to the anus, that forms the basis of the digestive canal, experiences a marked concussion: gentle purging has been thus effected by occasioning slight colics. Humboldt, after having detached the cuticle from the posterior part of the neck and back by means of two blisters, applied plates of metal to the bare cutis, and, at the moment of establishing a communication, he experienced sharp prickings accompanied with a sero-sanguineous excretion.

The excitatory arch may be constructed with three, two, or even one metal only, with alloys, amalgams, or other metallic or mineral combinations, carbonated substances, &c. (during the winter of the 8th year of the republic I employed with success pieces of ice, both as supporters or communicators); and it is observed, that metals, which are in general the most powerful excitators, induce contractions so much the more, as they have a greater extent of surface. Metals are all more or less excitants, and it is observed that zinc, gold, silver, pewter, are of the highest rank; then copper, lead, nickel, antimony, &c. without our being able to find any connexion between these different degrees of exciting power, and their physical properties, as weight, malleability, &c.

CXXVII. Galvanic susceptibility, like muscular irritability, is exhausted by a too long continued exercise, and is recruited by repose: immersion of the nerves and muscles in alkohol and opiate solutions, diminishes and even destroys this susceptibility, in the same manner, doubtless, as the immoderate use of these substances in the living man blunts and induces paralysis in muscular action: immersion in oxygenated muriatic acid revests the fatigued parts with the power of being acted on by the stimulus. Humboldt has observed that the spring season and younger frogs are more favourable to the production of phenomena; and that the fore-legs of these reptiles, by which they secure themselves on the back of the female by pressing her sides, are more excitable than their hind-legs; while, on the contrary, in the other sex the posterior extremities possess the greatest susceptibility. Hallé has convinced himself, by experiments made in the Medical School in Paris, that the muscles of animals killed by the repeated discharge of an electric battery, acquire an increase of galvanic susceptibility; and that this property subsists unchanged in animals destroyed by submersion in mercury, pure hydrogen gas, carbonated hydrogen, oxygenated, muriatic, and sulphureous acid, by strangulation, and by depriving them of air in the air-pump; but that it is diminished after death by drowning, by sulphurated hydrogen gas, azot, and ammoniac; and, finally, that it is totally annihilated in animals suffocated by the vapour of charcoal.

CXXVIII. Galvanic susceptibility is extinct in the muscles of animals of warm blood in proportion as vital heat is dissipated; sometimes, even when life has terminated in convulsions, contractility cannot be put into action, although warmth be not completely gone, as though this vital property were consumed by the convulsion amidst which the animals had expired. In those of cold blood, susceptibility, on the contrary, is more durable: the thighs of frogs, long after being separated from every thing, and even to the instant of incipient putrefaction, are influenced by galvanic stimuli, doubtless because irritability in these animals is less intimately connected with respiration, and life more divided among the different organs, which have less occasion to act on each other for the execution of its phenomena.

Irritability, therefore, as I have proved in another work, is not sufficiently durable in man, for galvanic experiments, instituted after death, to reflect any light on the greater or less diminution of this vital property in different diseases. Authors who have advanced that galvanic susceptibility is more deficient in subjects that died of scorbutic affections than in those taken off by inflammatory diseases, have therefore hazarded a probable conjecture, but which cannot be confirmed by experience.

Dr. Pfaff, professor at the university of Kiel, who is next to Humboldt in Germany for the success of his experiments on galvanism, has been so kind as to communicate to me the following facts, which few persons in France are acquainted with at the instant of my writing this paragraph.

The galvanic chain does not produce sensible actions, that is, contractions, until the moment it is completed by establishing a communication between the parts constituting it. During the time it is complete, that is, throughout the whole space of time that the communication remains established, every thing seems tranquil; nevertheless galvanic influence is not suspended: in fact, excitability is evidently increased or diminished in muscles that have been long continued in the galvanic chain, according to the differences of the reciprocal situation of the connected metals.

If silver has been applied to nerves, and zinc to muscles, the irritability of the latter increases in proportion to the time they have remained in the chain. By this method the thighs of frogs have been revivified in some degree, and afterwards became sensible to stimuli that had before ceased to act on them. By distributing the metals in an inverse manner, applying zinc to nerves, and silver to muscles, an effect absolutely contrary is observed; and the muscles that possessed the most lively irritability when placed in the chain, seem to be rendered entirely paralytic if they remain long in this situation.

This difference evidently depends on the direction of the galvanic fluid, determined towards the nerves or muscles according to the manner in which these metals are disposed: it is of some importance to be known, for the application of galvanic means to the cure of diseases. In cases where it is designed to augment a diminished irritability, it is better to employ the permanent influence of the galvanic chain by distributing silver and zinc, so that the former shall be nearer to the origin of nerves, and the latter placed on those muscles, the action of which it is required to restore when lessened or totally suspended, than to make use of the sudden, transitory influence that is instantly stimulant. Professor Pfaff informed me that he had successfully treated an hemiplegia by placing silver in the mouth and a plate of zinc on the paralytic arm: at the expiration of twenty-four hours of uninterrupted communication the latter part could perform slight motions. On the other hand, in order to diminish the energy of irritability in several spasmodic affections, it would be necessary to reverse the application of metals, to place the zinc as near as possible to the central extremity of the nerves, and the silver on their external terminations.

The Apparatus of Volta, or the Galvanic Pile.

CXXIX. It is curious to observe the connexions supposed by several philosophers to exist between electricity and galvanism. M. Volta has formed the following apparatus, which is described, as well as the effects it produces, in a paper presented by this learned man to the Royal Society of London: these effects prove the most striking analogy between these two orders of phenomena, as will be seen in the subjoined compendium. Raise a pile by placing a plate of zinc, a flat piece of wet card, and a plate of silver, successively, then a second piece of zinc, &c. until the elevation is several feet high, for the effects are greater in proportion to its height; then touch both extremities of the pile at the same instant with one piece of iron wire; at the moment of contact a spark is excited from the extremities of the pile, and luminous points are often perceived at different heights where the zinc and silver come into mutual contact. When proved by Coulomb's electrometer, the extremity of the pile relative to zinc appears to be negatively electrified; that formed by silver, on the contrary, indicates marks of positive electricity.

If we touch both extremities of the pile, after having dipped our hands into water, or, what is better, a saline solution, a commotion, followed by a disagreeable pricking in the articulations of the fingers and elbow, is felt.

This effect may be perceived by several persons holding hands, as in the experiment of the Leyden phial, and it is more evident in proportion to the smaller number of individuals that compose the chain, particularly when isolated.

Notwithstanding this great resemblance between the effects of galvanism and those of electricity, they have an essential difference: since Volta's pile constantly electrifies by itself, its effects seem to aug-

> ment in proportion as they are solicited, and soon restore themselves with greater power after having been exhausted by considerable discharges, while the Leyden phial once discharged requires to be refilled with electric matter: besides, the latter loses some of its electric properties by humidity, but those of the pile remain the same, when water is rushing down on all sides, and is only rendered inefficient by total immersion in this liquid.

If we place in a tube filled with water, and hermetically closed by two corks, the extremities of two wires of the same metal which are in contact at the other extremity, one with the summit, the other with the base of the galvanic pile; these ends, when separated only by the space of a few lines, experience evident changes at the instant the extremities of the pile are touched: the wire, in contact with that part of the pile composed of zinc, becomes covered with *bullæ* of hydrogen gas, that which touches the extremity formed by the silver is oxyded. If the ends of the wire immersed in water are made to approximate and come into mutual contact, all effects cease; there is no longer either disengaging of bullæ from one part, or oxydation on the other: the laminæ of zinc and silver are also oxyded in the pile, but only on the surfaces that touch the wet card, and very little, or not at all, on the opposite surfaces, &c.

Such extraordinary facts should awaken the attention of every philosopher, therefore they have been anxious to repeat and verify these experiments, to vary them, and rectify the errors into which the authors might have fallen; in fact, they have endeavoured to explain the manner in which the oxydation and production of hydrogen gas are effected.

Fourcroy attributes this phenomenon to the decomposition of water by the galvanic fluid, which abandons the oxygen to the iron that touches the positive extremity of the pile, then conducts the other gas invisibly to the end of the other wire, there to be disengaged: this opinion, supported by a great number of experiments collected into a memoir, and presented to the National Institute, appears the most probable of any that has been hitherto proposed.

The influence of galvanic phenomena is extended in proportion as experiments are multiplied, and they will soon belong as much to the province of chemistry as to the science of the animal economy. Nothing is even more difficult than to connect them together; each fact that is discovered, by furnishing some information, constantly leads to new difficulties.

General Consideration of the bony System.

CXXX. Man, like all animals of red blood (mammiferi, birds, reptiles, and fish), has an internal skeleton formed by a great number of articulated bones, and put into action by the muscles that cover them. Animals of white blood have no internal bones; hard, scaly, or stony parts cover them, and constitute what is called their external skeleton: there are animals absolutely destitute of hard parts, as zoophytes, several worms, and some insects. The composition of the substance of bones is nearly alike in all animals: gelatine and salts, with a calcareous base. The external skeleton of animals of white blood has a greater resemblance to the epidermis of those of red blood than to their bony system; it is destroyed and renewed like the cuticle: thus the shell of the crab is thrown off annually, when the substance of this crustaceous animal augments in volume, and is replaced by a new covering which is at first very soft, but gradually acquires the same consistence as the former; and, lastly, the skeleton of birds differs from that of all other animals, from its principal parts being cavernous, communicating with the lungs, and always filled with air, rarified by vital heat, which powerfully concurs to give them a specific lightness so necessary for their particular mode of existence.

The osseous system serves as a foundation to the animated machine, forms a solid support for all its parts, and determines the height of the body, its proportions, shape, and attitude. The body, without bones, would have no constant form, and could not move from one place to another but with difficulty: when these organs become soft by the loss of the calcareous salt, to which is to be attributed their characteristic firmness, the limbs are deformed; standing, and the different progressive motions, ultimately become impracticable. These are the effects of rickets, the nature of which disease is at present well known, although the mode of action of the causes that produce it, and appropriate remedies, are not, on that account, better understood.

The *columna vertebralis*, or spine, forms the essential and fundamental part of the skeleton; it may be considered as the base of the bony edifice, the centre on which the bones are supported in their different motions, since every considerable commotion and shock is communicated to it; besides, in its cavity is contained a continuation of the brain, which distributes the greatest number of nerves in the body.

The columna vertebralis, in order to serve as a support to all parts, and at the same time to protect the delicate organ within its cavity, as well as to conform itself to the varied attitudes that are requisite in life, should unite extreme solidity with sufficient mobility: it possesses both these advantages; the former in consequence of the extent of surfaces by which the bones composing it are articulated; from the volume, length, direction, and strength of their apophyses; from the number of muscles and ligaments attached to them, passing from one to another, while the latter is derived from the great number of bones of which the spine is formed. Each vertebra admits of a little motion, but when all move at the same time, their motions assist each other; there results a considerable aggregate motion, which can be estimated by multiplying the partial motion by the number of vertebræ.

The centre of motions on which the spine acts by bending forwards or backwards, is neither in the articulation of the oblique apophyses of each vertebra, as mentioned by Winslow in the Memoirs of the Academy of Sciences for the year 1730, nor in the cartilaginous symphysis that unites their bodies; nor do the extension and flexion of the vertebræ act on the two centres of motion, one of which was considered to be in this symphysis, and the other in the articulations of the apophyses, by Cheselden and Barthez, but rather on an axis that crosses the bone between its body and great aperture. The anterior part of the bone and its spinous process perform round this imaginary axis motions of the arch of a circle, which are not less marked from the smallness of their extent; and in these motions sometimes the articular surfaces separated by the intervertebral cartilage approximate, and this substance is compressed, while the oblique apophyses glide over each other, and have a tendency to separate: this happens in the flexion of the trunk; but in being returned to its state of extension the anterior surfaces separate from, while the posterior approximate towards each other, and terminate by coming into mutual contact throughout their whole extent, when the trunk is extended so far as the spinous processes permit.

The use of this range of eminences on the posterior part of the vertebræ is to set limits to the curvature of the trunk posteriorly, and to enable the muscles that effect this motion to act with greater advantage. When, from habit, these apophyses have been prevented from taking their natural direction, the trunk may be sent so far backwards as to make the body represent the arch of a circle. In this manner tumblers practise, from early childhood, who surprise us by the extraordinary flexibility of their bodies, so as to alter the natural direction of the spinous processes.

It was a matter of some importance for the motions of the spine to be effected by a great number of articulations: by this method the inflexions are less, and the organization of the spinal marrow, which requires powerful protection, is not altered. The fibro-cartilaginous parts that unite the bodies of the vertebræ, and are placed between them, are very elastic like every structure of that kind, and advantageously support the weight of the body. When pressure has been long continued they sink a little, their thickness is diminished; and as this effect takes place throughout all the intervertebral laminæ at the same time, our stature is visibly diminished: for this reason the body is always shorter at night than in the morning, and this difference may become considerable, examples of which are adduced by Buffon. The son of one of his most zealous colleagues (M. Guénaud de Montbelliard, to whom we are indebted for the greater part of the history of birds), a young man five feet nine inches in stature, when at the period of full growth, lost eighteen lines in height after having passed a night at a ball. This difference is also influenced by compression of the adipose structure at the heel, and which likewise forms a thick lamina on the soles of the feet.

The thigh is longer in man than in quadrupeds, and its proportional length invests him with the exclusive power of *sitting*.

Of the two bones of the leg, the tibia only serves as a column of support; the fibula, situated on its external margin, is too fine and slender to sustain the weight of the body, and its use is confined to the articulation of the foot at the external part; it supports this part, and prevents its dislocation outwardly by a too powerful abduction. In this motion the foot presses against the fibula, which is curved so much more towards the outside, as the individual advances in years, or has more frequently exerted this power of resistance.

This curvature, very prominent in the chefs d'œuvre of antique sculpture, gives a fulness to the bottom of the leg of the finest statues that does not well accord with our ideas of elegance and form. This proves that beauty is not invariable, as some philosophers have maintained, and that ideal perfection is not exactly the same in all ages, in nations which have acquired an equal degree of civilization. It is easy to verify this observation by the Apollo of Belvidere: his knees are rather large and near together; the foot is turned outwards, because the knee is inclined inwards; and this form has the finest expression in nature, who, by giving the femur an oblique direction inwards, causes the knees to be neither perfectly straight, nor makes an excessive disproportion between the small and calf of the leg.

Animals that climb, as the squirrel, the pole-cat, &c. the feet of which are in a state of continual abduction, have a very large and curved fibula.

The multiplicity of pieces of which the foot is composed, independently of the greater solidity that it gives these parts, is also of great utility in preventing the body from being too much shaken by the percussion of the sole of the foot in our various motions. A person jumping from a high place endeavours to alight on the toes, that the motion may be diminished in passing the numerous articulations of the tarsus and metatarsus, and not convey such a painful concussion to the head, which would be attended with danger: it is a well-known fact, that falling on the sole of the foot will occasion fractures of the neck, of the os femoris, commotions of the brain, and other organs.

The Structure of Bones.

CXXXI. Whatever difference there may seem to be between a bone compared with another organ, its composition is the same; parts absolutely similar enter into their structure, except only a saline, inorganic matter, which, when deposited in the cellulous part of its texture, constitutes firmness and solidity, the principal characters which distinguish bone from soft parts. This saline-terrene element is separated by macerating a bone in nitrous acid diluted with water; a phosphat of lime is then found to be decomposed by giving its calcareous base to the nitrous acid: the bone thus deprived of the principle of its consistence, softens, becomes flexible, and presents the appearance of a cartilage, which by long maceration ultimately resolves into a cellular texture similar to other parts. The bones, then, are only cellular parenchymata, the areolæ of which contain a saline crystallized matter that is separated from the blood, and with which they become incrusted by a power inherent and peculiar to their structure: the same result is obtained by making an inverse analysis. If a bone be boiled for several hours in Papin's digester, every organical part of it is dissolved and forms an abundant gelatine, and there remains a saline, inorganic concretion, which can also be obtained by calcination. The respective proportions of the saline and organized parts vary considerably at different periods of life; the bones of the fœtus are at first entirely gelatinous. At the time of birth, and during the first years of life, the organic part superabounds; the bones are therefore less liable to break, more flexible, and fractures are repaired with greater facility. In youth the quantity of each constituent part is nearly equal; in adults the calcareous earth forms almost two thirds of their substance; and, finally, by gradual accumulation in old age it superabounds, and obliterates the organized parts; therefore bones are then more brittle, frequently broken, and require a greater length of time in the cure. It may, in fact, be said, that the quantity of phosphat of lime deposited in the texture of bones is in a direct ratio of the age; and that, on the contrary, the energy of the vital faculties of these organs, their flexibility, elasticity, and aptitude to consolidate when their continuity is destroyed by any accident, are absolutely in an inverse proportion.

Anatomists distinguish three substances in bones, which are called compact, spongy, and reticular. The first, which is hardest, accumulated in the centre of long bones, at a part where the efforts of both extremities unite, affords this middle portion a degree of solidity necessary for resistance. The formation has been variously explained: some have affirmed that the hardness is occasioned by the pressure of both ends of the bone acting on its centre during growth, as the stalk and root of a plant press on its body. Haller says that it is formed by the pulsations of nutritive arteries that pass into long bones through their middle part; but, in that case, why are they not found as much towards the extremities, which receive arteries equally large and more numerous? In the work of ossification this substance appears first in the middle of the long bones, which confirms the assertion of Kerkringius, who maintained that our bones begin to indurate at those points which have to support the strongest efforts.

The spongy substance is situated in the middle of short, and in the extremities of long bones, where its accumulation presents two advantages, that of giving considerable bulk without an increase of weight, by which it is articulated with other bones on large surfaces (this was necessary for the solidity of their connexions); and that of separating from the parallel line the tendons passing about the articulations, of augmenting the angle formed by their insertion, and also of increasing the efficacy of muscular action. The mechanical hypotheses proposed by Haller and Duhamel on the formation of this spongy substance, independent of being very little satisfactory, should seem useless if it be considered that in the gelatinous bones of the embryo, the part to be occupied by the spongy substance, that is, the extremities of long bones, seems more voluminous than the rest: all the cells of the spongy substance communicate together, they are lined with a very fine membrane, and filled with medullary juice. The laminæ, which by various intersections constitute the parietes of these cells, become smaller and less numerous; the spongy texture forms in the medullary canal of long bones a reticular structure, the use of which is to support the membranous cavity that contains the medulla.

These three substances, notwithstanding their unequal degree of density, are, in fact, only one and the same substance differently modified; the reticular and spongy merely differ from the compact in containing less phosphat of lime, and in their texture being more expanded. The changes of bony texture which constitute laminated and smooth exostoses, the conversion of bones by acids into flexible cartilage, which is reduced by maceration to a cellular texture, prove that these three substances are identically the same, and only differ in density and the quantity of phosphat of lime deposited in the interstices of their texture.

It is believed that the compact substance is formed by an assemblage of concentric laminæ firmly united to each other, and consists of fibres that are transverse or longitudinal and closely connected: the exfoliation of bones exposed to the contact of air is advanced in proof of this opinion: but these laminæ, detached in a bone that exfoliates, prove nothing but the manner in which the destructive cause acts. The air, heat, or any other agent successively applied to different bony surfaces, establishes a distinction between them that did not exist in a natural state, and induces their successive destruction: certain parts, in which a lamellated structure is not admitted to exist, present this mode of decomposition. De Lassone has seen a small piece of human skin that had long remained in a cavern, detached in laminæ of extreme tenuity.

Life, which exists in a lower degree in the bones than in other parts, seems to animate their different substances variously, in proportion to the quantity of nerves and vessels that are distributed on them; it is therefore more active in the spongy substance; granulations arise more speedily from them in fractures, and the formation of a callus is effected with greater promptitude: caries, on the other hand, is more rapid in its progress, and is here more difficult to be counteracted.

Uses of the Periosteum and medullary Juices.

CXXXII. All bones, whatever be their situation, size, form, and composition, are covered by periosteum, a whitish, fibrous, dense, and serrated membrane, through which the vessels and nerves pass that penetrate into their substance. The periosteum is a membrane perfectly distinct from other soft parts, and from the bone itself, to the surface of which it adheres by means of nerves, vessels, and cellular texture, that pass from one to the other, and become so much the more intimately connected as we advance in age. The nervous and vascular fibres that pass through the substance of the bone, establish a direct sympathetic communication between its periosteum and the very delicate membrane that is expanded over its internal cavities, which secretes the medulla, and has received the name of internal periosteum. It is in consequence of this intimate connexion that the periosteum, after the medullary membrane has been destroyed by the introduction of a sharp instrument, as first tried by Troja, becomes detached from the bone that it covers; receives the phosphat of lime carried by the vessels that ramify in its texture; forms an incrustation of this salt that constitutes a new bone around the other, which maintains its uses, although it have not precisely the same figure: the isolated bone, deprived of nourishment and life by this artificial *necrosis*, moves in the centre of this recent osseous production, from which it may be extracted after a previous perforation. It is by means of the same sympathy that the blunt, deep-seated, nocturnal *osteocopi*, which afflict patients heated in bed during the advanced period of venereal affections, pains which seem to have their seat in the centre of the long bones, occasion a swelling of these bones and of the periosteum.

The following experiment of Professor Chaussier most clearly elucidates the real uses of the periosteum. It consists in detaching this membrane from certain points of the bony surfaces, or of removing the bones themselves after a complete dissection of their external membrane: by these means are induced the formation of a new bone and origin of various concretions, when the periosteum is merely stripped off. The use of this membrane, therefore, is to regulate the distribution of the nutritive juices of bone, since granulations are formed with more or less irregularity at the denuded points; besides, this property is common to all fibrous membranes, the destruction of which is followed by excrescences that arise from the organs covered: a phenomenon absolutely similar takes place after a partial removal of the bark from trees. Perhaps even the periosteum, like the covering of vegetables, contributes to the increase of thickness in bones by the successive induration of its most internal laminæ.

The marrow that fills the central cavities of long bones, and the medullary juices contained in the cells of the spongy substance, have the greatest analogy to adeps by their chemical nature, and doubtless also by their uses (LXXV.). The proportion of both these humours is always relative; in very thin persons the bones contain only an aqueous, very fluid liquor; and although this liquor constantly occupies the internal cavities of these organs, the solid parietes of which cannot press towards each other, it contains much fewer particles in the same volume, and its quantity, like that of the adeps, is, in fact, diminished. It is the product of arterial exhalation, and does not serve for the immediate nutrition of the bone, as believed by the ancients, at least to an exclusive degree, since the generality of long bones in the numerous class of flying birds are excavated by air-canals, and destitute of this humour. It is very difficult to point out the uses of the marrow and medullary juices. Do they exist only to fill the cavities which nature has formed in the harder parts to render them lighter? Is it possible for a portion of these liquids to transude through the substance of articular cartilages, at least in the large articulations, and mix with the synovia, to augment its quantity, to render it more unctuous, and better adapted to obviate friction of articular cartilages? If such transudation can take place after death, why should it not be effected when all parts are in a state of warmth and vital expansion?

Articulations, Cartilages and articular Ligaments, synovial Humour.

CXXXIII. The articulations of different parts of the skeleton are not all so disposed as to admit of motions; several, as the sutures, by reciprocal serrated edges, by harmonic or squamous juxtaposition or gomphosis, are absolutely immovable, and, on that account, called synarthroses: all the other articulations, whether the bones be in immediate contact (*diarthroses by contiguity*), or there be another substance interposed between them (*diarthroses by contiguity, or amphiarthroses*), are possessed of a greater or less degree of mobility. We here speak only of movable articulations, whether they admit of extensive motions, and in all directions, *orbicular diarthroses;* or whether the bones merely act in opposite directions, *alternate diarthroses or ginglymi;* by forming an angle, *angular ginglymi;* or by performing rotation one on the other, *lateral ginglymi.*

In all articulations the bony surfaces are covered by laminæ of a substance softer than that of the bone: this is articular cartilage, which answers the double purpose of giving the extremities of bones a smoothness necessary for their easy gliding over each other, and to assist motion by the great elasticity they possess. Morgagni has proved, that of all animal substances, cartilages are most elastic: their structure is very different from that of bone, even when the latter is cartilaginous, since articular cartilages do not become ossified in the most aged persons. They are formed of very short fibres in the longitudinal direction of bones, closely pressed together, and firmly united by other fibres in a transverse direction. This vertical situation of the greater number of cartilaginous fibres, demonstrated by De Lassone, is very favourable to their elastic reaction; the capsular ligament, of extreme tenuity, is reflected over them, and unites with their perichondrium, as taught by Bonn, Nesbit, and several other anatomists.

Independently of the cartilages that cover the extremities of bones, there are found in certain articulations fibro-cartilaginous lamellæ placed between the articular surfaces. These intermediate parts are seen in the articulations of the maxilla inferior with the temporal bones, in that of the femur with the tibia, in that of the sternum with the clavicle; and it is to be observed that all these articulations perform many motions, as those of the maxilla, or suffer considerable pressure, as those of the knee and sternum. This latter admitting of very little motion, and being the point to which all exertions of the superior extremity are transmitted, required an apparatus of this kind, which is well adapted to diminish the effect, as far as relates to the trunk, since the motion impressed is partly lost in the action of the inter-articular cartilage.

We shall not recapitulate what has been said (LXXII.) on the secretion of the humour that lubricates articular surfaces, facilitates their motions, and maintains their contiguity. Its quantity is in a direct ratio of the extent of these surfaces, and of the membranous covering by which they are surrounded; it is also proportionable to the frequency of motions that each articulation can admit.

The liquor elaborated by glandulo-cellular fasciculi, situated in the vicinity of articulations, is called synovia, secreted by the membranous capsules that surround them, and are reflected over the articular extremities of bones covering their cartilages; so that these extremities are no more contained in the proper cavity of the capsule, than the abdominal viscera are in that of the peritoneum, as observed and elucidated by *Bonn* towards the middle of last century.

Synovia is heavier than common water, perfectly void of colour, and more viscid than any other animal liquor. A great proportion of albumen is found in it, which exists in a particular state, and disposed to concrete into filaments by the addition of acids, as observed by Marguerou, who is the first that furnished a tolerably exact analysis of synovia. It also contains some muriat and carbonat of soda, phosphat of lime, the whole dissolved in water, which constitutes three fourths of its weight.

Motion, as observed in another part of this work, seems to be the stimulus proper for synovial secretion, since it is more abundant when repeated friction in the articulations maintains a continual irritation.

The gout is experienced in articulations that perform most motion and suffer the strongest pressure. Its first attack, as observed by Sydenham, is in that of the great toe, with the first bone of the metatarsus, an articulation that supports the weight of the whole body, and is most exercised in various progressive motions.

The muscles that surround articulations afford them much greater strength than the ligaments situated in their vicinity: in fact, if these muscles become paralytic, the limb, by its weight, stretches the ligaments, which elongate and permit the head of the bone to leave the cavity which it occupied. It is thus that loss of motion and atrophia of the deltoid muscle induce luxation of the humerus, the orbicular ligament of the articulation of this bone with the scapula not being sufficient to retain its head in contact with the glenoid cavity. The columna vertebralis dissected, so that the ligamentous attachments only remain, is broken by a weight much inferior to that which it would have supported, before it had been deprived of the muscles that are attached to it.

Standing.

CXXXIV. That action is so called by which man supports himself erect on a solid surface. In this straight position of all our parts, the perpendicular line passing through the centre of gravity of the body (the centre of gravity in an adult man is between the sacrum and pubis) should fall on a point of the space formed by the soles of the feet. Standing is most firm when a line continued from the centre of gravity of the body is exactly perpendicular to its base of sustentation (which is the space circumscribed by the feet, whatever be their degree of separation); but this line may cease to be vertical without inducing a fall, since muscular action soon re-establishes the equilibrium destroyed by its obliquity. If this obliquity should become so great as to admit of the line continued from the centre of gravity beyond the limits of the base of sustentation, falling is inevitable on that side towards which this line is inclined.

> *Quotiescunque linea propensionis corporis humani, cadit extra unius pedis innixi plantam aut extra quadrilaterum, comprehensum à duabus plantis pedum, impediri ruina, à quocumque musculorum conatu non potest.* Borelli, Prop. 140.

> Solidity of standing depends, therefore, partly on the breadth of the feet and of their separation: it is very imperfect when we support ourselves on one foot only, and we are then obliged to exert continual efforts to prevent the centre of gravity from exceeding the narrow limits of its base of sustentation.

If the centre of gravity recline backwards, and there should be danger of falling on the occiput, the extensor muscles of the leg contract strongly, so as to prevent flexion of the thigh, while other powers have a tendency to bring forwards the superior parts, and give a vertical direction to the line continued through the centre of gravity; and if its obliquity should augment, although the extensors of the leg enter into action, so that nothing can retain the body which its own weight carries towards the ground by a motion that the quickness of the fall accelerates, these muscles will redouble their efforts to prevent it, and in this violent contraction may fracture the patella transversely, as I have explained in a memoir on the fractures of this bone.

I consider it of some utility to enlarge on the mechanism of standing more than has been hitherto done, since an exact knowledge of this mechanism facilitates the explanation of progressive motions: walking, running, &c. require the body to be erect for their execution; therefore when it is understood by what powers the centre of gravity of the body is maintained perpendicular on the base that supports it, the different methods by which it changes situation, and carries itself from one place to another, will be easily comprehended.

Let us first examine the question so long discussed, to know whether man be designed to support himself, and walk on his four extremities during the early period succeeding birth.

Standing would be for man a state of repose if his head were in perfect equilibrium with the columna vertebralis; if the latter, forming the axis of the body, and equally supporting in every sense the weight of the abdominal and thoracic viscera, fell perpendicularly on the horizontal pelvis; and, finally, if the bones of the inferior extremities formed columns exactly vertical to it: but none of these circumstances exist in the human machine. The articulation of the head does not correspond with its centre of gravity; the thoracic and abdominal viscera, the parietes of the cavities containing them, almost exclusively press on the anterior part of the spine; this rests on an oblique base, and the bones of the inferior extremities which touch by convex and slippery surfaces are more or less inclined towards each other. It is necessary, therefore, that an active power should continually watch to obviate the falls which their weight and direction would incur.

Standing, in certain animals, is not a state of effort or exertion as it is to man, which is proved by the following fact, from the observation of Dumeril: Birds on the banks of a river, and particularly the grallæ of Linnæus, as herons and storks, obliged to exist amidst marshy places and muddy waters, where there are reptiles and fish by which they are supported, have long surprised naturalists by the protracted immobility of which they are capable in the state of standing. This singular faculty, so necessary to beings obliged to wait for their prey more by chance than industry, is in consequence of a particular disposition of the articulation of the leg with the thigh. The surface of the articulation of the femur, as noticed by Dumeril in the feet of a stork (*Ardea ciconia*, L.), presents near its centre a depression, into which a projection of the tibia enters. In order to produce flexure of the leg, this eminence must be disengaged from the cavity that receives it, which it cannot effect without pulling several ligaments which keep the leg extended in standing, flying, and other motions of progression, without requiring the aid of the extensor muscles.

This power resides in extensor muscles that maintain our parts in a state of more perfect extension, and render the act of standing more firm in proportion as they are counterbalanced by considerable antagonism, and also by their mechanical disposition, having less tendency to flexion. It will not be difficult to prove that in early life all our parts are not favourably disposed for the operation of powers that effect standing; besides, as we have before observed (CXXIII.), these powers are deficient in a degree of energy sufficient to form an equilibrium with those whose action is directly opposed to them.

The relative weakness of the extensor muscles is not the only obstacle to the act of standing in early life; other causes, which will be shortly examined, concur to deprive the new individual of the exercise of this faculty.

The articulation of the head with the spine being nearer the occiput than the chin, and not corresponding with its centre of gravity, when left to its own preponderance would fall on the superior part of the thorax. It has a greater tendency to fall in proportion to its volume; and since it is very large in newly-born infants in comparison with other parts of the body, and their extensor muscles participate in the debility of every other class of muscles, it falls on the anterior part of the thorax, and carries the body down with itself: the weight of the thoracic and abdominal viscera tends to produce the same effect.

Growth always proceeds from the superior towards the inferior parts; and this constant law completely eludes all mechanical explanation: it is not the same with the effects that should result from this unequal growth of parts relative to standing.

The inferior members that serve as a base to the whole edifice being very imperfect at the period of birth, the superior parts resting on such a foundation must necessarily fall, and carry with them the others.

The relative weight of the head, the thoracic and abdominal viscera, therefore tend to carry forwards the line, agreeably to which all parts of the body press on the surface that supports it, a line that should be exactly perpendicular to this base for standing to be firm and perfect. The following fact strengthens this proposition: I have observed that children, whose head is very large, belly projecting, and viscera superabounding in adeps, stand upright with difficulty; and it is hardly before the completion of their second year that they dare venture to confide in their own strength: they remain liable to frequent falls, and have a natural tendency to resume the state of the quadruped.

The spine in an infant, as in an adult, does not describe three curvatures alternately disposed in a contrary direction: it is almost straight, but longitudinally forms a slight curvature with the concavity forwards. This incurvation, which can only be attributed to the flexion of the trunk during pregnancy, is likewise more strongly marked towards the termination of utero-gestation.

It is known that the different curvatures of the spine powerfully assist standing, by augmenting the extent of the space in which the centre of gravity can be balanced without being extended beyond its limits; and relative to this use it may be considered as having a volume defined by two lines falling from the anterior and posterior part of the first cervical vertebra to the sacro-lumbar symphysis. These two lines, near together at their superior, but suspended at their inferior part, should be the chords of arcs and the tangents of curves described by the columna vertebralis; so that the spine may be considered as having an imaginary thickness, superior to its real magnitude.

In the new-born infant, the defect of alternate curvatures not only contracts the limits in which the centre of gravity may vary, but also the disposition of the only curvature that exists favours a flexion of the trunk, and consequently the inclination forwards, and falling in that direction. This inflexion of the spine in the fœtus and infant is analogous to that of the columna vertebralis in several quadrupeds.

This curvature is strongly marked in the hog, the back of which animal presents a very prominent convexity; and this disposition, necessary for the columna vertebralis to support the enormous weight of its abdominal viscera, has the greatest influence over the mechanism of its progressive motions. When affrighted by any noise, it starts forwards by jumping, and it is easy to perceive the spine forms an arch at each leap, then becomes straighter; and that the animal hastens its course principally by the tension and relaxation of the vertebral arch.

The disadvantage resulting from the defect of alternate curvatures in the columna vertebralis of the infant, is rendered still greater by the absolute deficiency of spinous apophyses. It is well known that the principal utility of these projections is to separate the power from the centre of the motions of the vertebræ, to increase the length of the lever by which it acts on the trunk to make it straighter, and to render its action by that more efficacious. At the period of parturition the vertebræ are absolutely destitute of spinous processes: they afterwards arise from the part where the laminæ of these bones are united by means of a cartilaginous portion that completes the vertebral canal posteriorly. The erector muscles of the trunk, weakened by the constant state of flexion during utero-gestation, still lose the greater part of their force by the unfavourable manner in which they are applied to the part upon which they are to act.

Flexion of the head not only depends on its considerable weight, but also on the defect of spinous apophyses in the cervical vertebræ; since the more considerable motions of this part take place much less in its articulation with the atlas than in those of all the other cervical vertebræ.

The pelvis of the infant is very little developed; its superior aperture very oblique: the viscera to be afterwards inclosed in its cavity are then, in a great measure, above it. This obliquity of the pelvis should necessarily require the continual straightening of the spine, in order that the line of direction of the centre of gravity should not be conformable to the natural tendency that inclines it forwards; on the other hand, the spine, reposing on a narrow pelvis, is less firm, and perhaps more easily drawn beyond the limits of sustentation. Finally, the small extent of the pelvis, joined to its obliquity, occasions the ill-supported viscera of the abdomen to press on the anterior and inferior part of the abdomen, and facilitate the fall of the body in that direction.

The patella, or rotula, which has a double purpose of strengthening the knee, before which it is placed, and of increasing the effective power of the muscles of the leg by separating them from the centre of motions of this articulation, and augmenting the angle in which they are inserted into the tibia, does not exist in new-born infants. The portion of the tendon of the extensors of the leg, in which this bone is hereafter to appear, is only of a firmer texture and cartilaginous hardness.

From the defect of the point of support results a continual tendency of the leg to be bent on the thigh, and from the parallelism of its extensor muscles arises almost a complete abolition of their effective powers: their antagonists then carry this member into a flexion that is more considerable, as it is but imperfectly counteracted by the tendinous portion situated on the anterior part of the knee.

The length of the os calcis, the extent by which it exceeds posteriorly the inferior extremity of the bones of the leg, concur to give stability to standing by elongating the arm of the lever, by which the extensor muscles of the foot perform their actions on this part; and since, in the young infant, this bone is shorter, and has a less degree of projection backwards, the power of these muscles, the insertion of which takes place near the centre of the motions of the foot, is considerably diminished.

Man has larger feet than any other animal; and it is to this more considerable extent of his base of sustentation that he, in a great measure, owes the advantage possessed, of only having occasion for one or two of his extremities to support the weight of his body in standing and in different progressive motions; while other mammiferi cannot support themselves, at least during a certain time, without leaning on three of their extremities. When I say that man, from the extent of his feet, has a body that rests on a larger base than that of any other animal, I make an abstraction for the space that these parts may circumscribe by their separation: in fact, this space is much more considerable for quadrupeds than for man. Nature has compensated the disadvantage arising from the smallness of their feet by the separation of these parts; and if she has rendered a biped station impossible to be performed, she has conveniently secured the mode of standing peculiar to them.

The feet of the ourang-outang, which, by the general disposition of its organs, presents such a striking conformity with the human species, resemble a hand roughly organized, better adapted to cling to trees, on which this animal is to seek for food, than to perform the uses derived from those of man. On the same principle, standing on two feet, which it practises on certain occasions, is to that animal neither more convenient nor natural; and as a philosopher, from the testimony of several travellers, observed, if pressing danger obliges it to escape, or to leap, by falling on its four feet, the true origin of this animal is easily discovered: it is reduced to its just scale of gradation by quitting the imposing countenance, and we no longer see it but as an animal to which the specious mask, as well as to a great number of men, does not add a single virtue.

Of all parts of the new-born infant, the feet are the least developed; its body is ill supported on this narrow base, and the line continued from its centre of gravity, which so many other causes tend to carry beyond its base, more easily exceeds its limits in proportion to the narrowness of extent.

The generality of varieties that we have just examined arise from the manner by which the distribution of nutritious juices is effected in the fœtus. The umbilical arteries carry from the mother, blood, propelled by the aorta towards the inferior parts, and only send off small ramifications to the pelvis and its dependent parts: thus the development, mostly proportional to the quantity of blood which organs receive, is very little advanced in certain parts at the time of birth, while in the head, trunk, and superior extremities, it is arrived at a considerable degree of perfection.

The new-born infant is, therefore, analogous to quadrupeds by the physical disposition of its organs. This analogy is more marked in the earlier period of the embryo's formation; and it seems to me a general proposition that organized beings resemble each other so much the more as they are observed nearer to the first period of their existence; and that the differences which characterize them become manifest in proportion as the actions of life are reiterated in the organs.

Therefore, power unequally distributed over muscular parts, and the unfavourable disposition of those parts to which the powers are applied, render it impossible for the new-born infant to maintain itself in an erect posture, that is, to retain the small line of direction of the body in a situation approaching a perpendicular to the base of support. But as the being advances in years, the preponderance of the flexor muscles over the extensors ceases to be excessive; the proportional volume of the head, that of the abdominal and thoracic viscera, the curvatures of the spine become complete; the spinous apophyses of the bones composing it are formed; the pelvis enlarges in breadth, and diminishes in obliquity; the patella becomes ossified, the os calcis extends more backwards; the relative smallness of the feet diminishes, and the infant gradually becomes capable of supporting itself erect by touching the ground with both feet, or even one only.

Of all animals, man is the only one that can enjoy this advantage when all his organs are sufficiently perfected. The following are some of the principal causes that invest him with this prerogative.

CXXXV. Although the articulation of the head with the spine does not correspond with its centre of magnitude nor of gravity, and though it is nearer to the occiput than to the chin, its distance from the latter part is much less in man than in the ape and other animals, the occipital bone of which, according to the observation of Daubenton, is so much nearer to the posterior extremity of the head as they bear less resemblance to the human species. The head, therefore, is nearly in equilibrium with the spine that supports it; at least, a smaller degree of power is required to retain it in a natural position; while the head of the quadruped, which is continually inclined towards the earth, presents the necessity of being retained by a cause capable of great and continual resistance. This cause is manifest in the posterior cervical ligament, so remarkable in these animals; it is attached to the spinous apophyses of the vertebræ of the neck, and to the external projection of the occipital bone, more strongly marked in them than in man, in whom the posterior cervical ligament exists by only a simple cellular line, forming an accurate division between both sides of the neck.

The alternate curvatures of the spine, the breadth of the pelvis and feet, the considerable powers of the extensors of the feet and thigh, &c. all these favourable conditions united in man, are deficient in animals: but on the same principle that in the latter every thing concurs to render standing on two feet impossible; so every thing in man is disposed so as to make it very difficult for him to support himself on four extremities. In fact, independently of the great inequality that exists between the superior and inferior members, a difference in length, which, being less sensible in early life, renders it less inconvenient for infants to move on their hands and feet; yet these four extremities do not furnish a support for the body equally solid. The eyes, naturally turned forwards, are directed towards the earth, and unable to comprehend a great degree of space, &c.

It is therefore impossible to agree with Barthez, in admitting the infant to be, naturally, a quadruped during infancy, since it is then only an imperfect biped (CXXXIV.); nor that it can walk on four points through life, if this habit, which had been acquired in early infancy, be not corrected.

CXXXVI. Very little has been added to what Galen observed in his admirable work on the structure of parts, concerning the respective advantages attached to peculiar conformations of the superior and inferior extremities. It is easy to discern that nature, in conciliating as much as possible the elements of force and mobility, has caused the former to predominate in the structure of the inferior extremities, while she has sacrificed force to facility, precision, extent, and promptitude of motions in the construction of the superior extremities.

In order to be convinced of the fact, it is only necessary to compare, under these points of view, the resistance of which they are capable, and the motions they can permit, the pelvis to the scapula, the femur to the humerus, the leg to the fore-arm, and the foot to the hand. (See Anatomical Considerations on the Neck of the Femur, that I have placed at the beginning of a Memoir, called *Dissertation anatomico-chirurgicale sur les Fractures du Col du Femur*, Paris, An 7.)

The inferior extremities, when their bones are covered by the soft parts, present the appearance of a cone or reversed pyramid, which, at first, seems contrary to the intention of nature; but if the osseous parts be divested of the surrounding fleshy portions, it will be perceived that these solid supports form a pyramid, the base of which is constituted by the feet, and diminishes in ascending from the leg, composed of two bones, to the thigh, which contains only one.

If we investigate the utility of the inferior extremities, being formed by several detached pieces, it will be found that they are, on such account, more solid than if they had been of one bone; since, from a theorem demonstrated by Euler (*Methodus inveniendi Lineas curvas*), two columnæ of the same substance and diameter have solidity in an inverse ratio of the squares of their height; that is, of two columns of equal substance and diameter, but of different altitude, the shorter is stronger.

Thus has nature multiplied these columns in the extremities of quadrupeds by raising the heel and different parts of the foot, the bones of which have been lengthened to form so many secondary legs. These numerous columns, placed one above the other, are alternately inclined, and habitually bent in quadrupeds swift of foot, and in those which jump, as the hare and squirrel; while in the ox, and more particularly the elephant, they are all on the same vertical line; so that the enormous mass of the latter of these animals is supported on four pillars, the component parts of which admit of so small a degree of motion on each other, that St. Bazile has fallen into the error of Pliny, Ælian, and several authors of antiquity, who affirm that there are no articulations in the legs of these monstrous animals.

The long bones which constitute the inferior extremity are excavated internally by a canal that increases their solidity; for, agreeably to a theorem explained by Galileo *(Opere, tomo secondo)*, two hollow pillars of the same substance, and of equal weight and length, have powers between them, as the diameter of their internal excavations.

The breadth of the surfaces by which the bones of the inferior extremities correspond with each other, powerfully concurs to add stability when these bones are vertically drawn, as in standing. There is no articulation effected by more extensive surfaces than that of the femur with the tibia and patella; nor is there any one among the orbicular that presents a greater number of points of contact than the articulation of the bones of the thigh with those of the pelvis. The celebrated Professor Barthez observes, that when the body is erect the head of the femur and the cotyloid cavity of the os innominatum that receives it, do not touch in extensive surfaces. But I am of opinion, on the contrary, that the mutual contact of these two bones is in no situation more complete; the small line of direction of the superior part of the femur is then exactly perpendicular to the surface of the cotyloid cavity, which surrounds and touches in all its points the spherical eminence of this bone.

The collum that supports the head, by separating the thigh from the cavity of the pelvis, augments the extent of space in which the centre of gravity may exist without being carried beyond its limits.

The state of standing does not imply a perfect immobility; it is, on the contrary, accompanied by motions of vacillation, that are more strongly marked in proportion as the individual may be deficient in force and vigour. These continual agitations, although little obvious in a man erect, depend on the incapacity of the extensor muscles to long maintain a state of contraction; they relax suddenly, and the momentary relaxations of the extensors are more frequent in proportion to the debility of the individual.

Some physiologists have given a very inexact idea of standing, by making it dependent on a general effort of the muscles; the extensors only are, in fact, active: the flexors, far from contributing towards this act, tend to derange the connexion of bones necessary to render this state durable and permanent. This explains the reason why standing occasions more fatigue than walking, which alternately exerts and relaxes the flexors and extensors of the extremities.

Yet it must be admitted, that, to render standing more secure, we sometimes contract the flexors in a moderate degree; then this great portion of the real power of muscles, which acts in the same direction as the levers to be moved (CXXIV.), and which is completely lost in the different motions they imprint, is found to be usefully employed to approximate the articular extremities, to press them against each other, and to maintain their exact superposition necessary for the rectitude of the body. I do not know that any person had hitherto mentioned this use of the most considerable portion of the muscular powers, which were considered to be entirely lost by the unfavourable disposition of the organs of our motions.

The centre of gravity, or the projected line, agreeably to which all parts of the body press on the base of support, has a greater tendency to incline forwards than backwards; and falls anteriorly are more common and easy.

This tendency is less remarkable in persons of a spare habit and of tall stature. It is observed that the generality of these individuals walk a little curved, or with a roundness of shoulders, not so much from the habit they contract by stooping, as to prevent the centre of gravity from being carried backwards: pregnant women, dropsical persons, and those who are corpulent, on the contrary, recline in the latter direction for a reason diametrically opposite, and easy of explanation.

Thus has nature ordered the motions of the hands, which we carry forwards to moderate falls, prevent too violent shocks, and weaken the effect of them; at the same time she multiplies the means of protection on the sides which the hands cannot defend, she has therefore given an increase of thickness to the posterior part of the cranium: the skin covering the nucha and back is of much greater density than that of anterior corresponding parts. The scapula is connected with the sides, and protects the posterior part of the thorax; the spinous processes and columna vertebralis exist the whole length of the back; the bones of the pelvis are broadest posteriorly, &c.

Falls are more severe in proportion as the articulations approach the state of perfect extension; similar accidents to the infant, whose limbs are in a state of habitual flexion, are much less dangerous than to a strong and robust adult, whose body falls as an *entire mass*, if I may be permitted to use the expression. The falls of skaters in gliding over the ice frequently prove mortal by the fracture of the cranium, which, situated at the extremity of a long lever, formed by the whole body, the articulations of which are extended, strikes the smooth and solid base with a quantity of motion that augments the celerity of the fall.

On Walking, Running, and Leaping.

CXXXVII. These three species of progressive motions are connected by many intermediate gradations, so that it is often difficult to distinguish them: there is, in fact, very little difference between walking and a certain manner of running; and the latter action is most frequently effected by the combined mechanism of walking and leaping. In the most natural kind of walking, we first balance the body on one of the feet, then bending the opposite foot on the leg, the latter on the thigh, and the thigh towards the pelvis, we shorten this extremity, at the same time we carry it forwards, extend the bent articulations, and when it is firmly placed on the earth, or base of support, we incline the body forwards, and carry the centre of gravity in this direction, and by making the opposite limb perform the same motions, we proceed with greater celerity if equal strength be exerted, in proportion to the length of the levers on which the centre of gravity is alternately carried. The weight of the body with respect to the inferior extremities may be compared to that of a vehicle, which passes in succession on the different spokes of its wheels.

The centre of gravity does not move in a right line, but between two parallels, in the intermediate space of which it describes oblique lines, which pass from one to the other by forming true *zigzags*. The oblique direction of the head of the femur explains the lateral motions of the body during walking: the arms, which move in a direction contrary to that of the inferior extremities, perform the office of balancing, preserve the equilibrium, and correct the vacillations, which would be much more perceptible if the heads of the thigh bones were in an horizontal instead of an oblique direction. The impulses communicated to the trunk are reciprocally counterbalanced, and it moves in the diagonal of the parallelogram, of which they constitute the sides. The breadth of the feet and a moderate degree of separation complete walking, by affording the centre of gravity a more extensive support; therefore, when we walk on a movable and insecure surface, we separate these supports to comprehend a greater base of sustentation. Men who have been long accustomed to the sea contract this habit of extending their feet to such a degree, which is indeed necessary for their support during the rolling and motion of the vessel, that they cannot divest themselves of it when on land, and are easily distinguished by their manner of walking. A sailor is not capable of performing any active service until he has acquired what naval men call the *sea-step;* that is, when he is accustomed to walk with confidence on the deck of a ship in a storm.

Woman, whose feet are naturally smaller, is less secure in walking; but should we therefore conclude, with the most eloquent writer of the eighteenth century, that this smallness of foot is relative to the necessity she has of running away to be obtained? The concave form of the soles of the feet, by causing them to be better accommodated to the inequalities of the ground, contributes to strengthen the body in walking and other motions of progression. In walking there is an intermediate moment between the beginning and end of a step, during which the centre of gravity is in the air; it continues from the instant that this centre leaves the foot behind, to that point of time when it is restored to the other foot carried forwards.

In running, when the foot behind leaves the ground, and before the other that is carried forwards is firmly placed the centre of gravity remains for a moment suspended; it then moves in the air, propelled by the force of projection, the exertion of which principally effects jumping.

The mechanism of running is the same as that of walking; the steps are not greater, but merely succeed with greater celerity; the centre of gravity is conveyed from one leg to the other with more rapidity, and falls are more likely to ensue. The prompt repetition of the same motions during running requires a high degree of irritability in the muscles that move the extremities; and as the energy of this vital property is proportioned to the extent of respiration, and to the quantity of aërial principle which the blood has acquired in passing through the lungs, persons that run respire frequently, and at short intervals, without extreme dilatation of the thorax. It was necessary for the parietes of this cavity to have a great degree of fixity during running; for it becomes the point on which are incumbent the powers that retain the pelvis and loins, and prevent these parts from forming a tottering base to the inferior extremities. Those are the best runners who have the most extensive power of holding breath, that is, who can maintain the greatest degree of permanent dilatation of the thorax: when disputing for victory of the course, they are seen to throw back the head and shoulders, not only in order to correct the propension of the line of gravity forwards, but also to render the cervical spine, scapulæ, clavicles, and humerus immovable, and to make them a fixed point for the action of muscles that are auxiliary to respiration.

Leaping, in man, chiefly depends on the sudden extension of the inferior extremities, of which all the articulations have been previously put into a state of flexion: the angles of the feet, knee, and hip, become obliterated, and the extensor muscles contract almost in a convulsive manner when the body leaves the base of support. This effect of all parts is not peculiar to the inferior extremities when the leap is considerable; its influence is then extended to the spine, which performs an action similar to the unbending of a bow. Professor Barthez, to whom may be attributed the explanation of this mechanism (for Borelli and Mayow had only comprehended it in a confused manner), carries his ideas perhaps a little too far, when he considers all repulsion on the part of the ground as imaginary. This reaction, admitted by Hamberger and Haller, certainly takes place when leaping is exercised on an elastic surface; and it is by these means that the rope-dancer raises himself, without great efforts, on the base of support. Momentary contraction of the extensor muscles is so strong in extending the limbs, and giving the body a powerful projection, that in this effort the tendons of these muscles, or even the bones into which they are inserted, are divided transversely: dancers, on this account, are very liable to fractures of the patella, which happen at the instant they are making the greatest exertion to spring in a perpendicular direction.

If leaping or jumping merely consist in the sudden efforts of the inferior extremities, the articulations of which are alternately bent, it ought to be more considerable in proportion to their length, the excess of flexure on each other, and energy of contraction in the extensor muscles.

Leaping animals, as the hare, squirrel, &c. have posterior extremities that are very long when compared with their anterior structure; besides, their different parts are susceptible of the greatest flexion.

This theory of leaping would appear to be contradicted by the singular fact noticed by Dumas, of a leaper absolutely deprived of thighs, who surprised the spectators by his address and agility. But could not the pelvis, the spine, and more especially its lumbar portion in this particular case, supply, by possessing greater mobility, the defect of the longest of the three levers composing the inferior extremity?

Swimming, Flying, and Creeping or Reptation.

CXXXVIII. Few animals support themselves on the surface of a liquid with more difficulty than man; yet the specific weight of his body is not much above that of an equal volume of water: sometimes, even when abounding in fat, the weights are equal, and it is observed that corpulent persons can swim with less efforts. But this weight is not equally distributed on all points of the supporting fluid; the head, the relative weight of which is very considerable, is a principal obstacle to the facility of swimming, and some difficulty is required to keep it above the water to maintain a free passage for air into the lungs through the mouth and nostrils: the superior and inferior extremities act in succession, and encompass water which is expelled backwards and downwards, while the weight of the body is supported between the extended extremities. In these different motions there are successive flexion, extension, abduction, and adduction of the extremities. The greater portion of muscles of the body act by making the parietes of the thorax their fixed point, and the swimmer keeps the chest dilated by a constriction of the glottis, while a considerable volume of air is retained in the lungs: this continued dilatation has also another advantage, by rendering the body specifically lighter.

Fish, on the contrary, possess a structure adapted to the element they inhabit; the form of their body, terminating at every part in acute angles, is very convenient for separating columns of a liquid. A bladder filled with azot, which is discharged by volition of the animal, renders their specific lightness above or below that of water according to the quantity of gas contained; and, finally, their tail acted on by very strong muscles may be considered a powerful oar, the repeated motions of which propel the animal forwards, while the fins, like so many secondary means, facilitate and direct its motions.

Birds, the body of which distended by air is also covered with feathers almost as light, swim with the greatest facility when their flat body presents a broad surface on the water, and the toes of their feet are connected by membrane, as observed in the numerous class of *palmipedes*, or aquatic birds.

Swimming, however, is not the most natural kind of motion: nature having designed them to inhabit the air, has endued them with great specific lightness, extending their lungs into the abdomen by membranous sacs, and also through the principal parts of the bony compages by means of air-canals, affording them at the same time considerable muscular powers. They present a broad surface on the air when their wings are extended; besides, the pectoral muscles that put them into motion are capable of striking with more force, and of repeating the percussion with more rapidity, than in any other animal. Those who have believed in the possibility of man supporting himself in the air after having rendered himself specifically lighter, did not recollect that it was impossible to invest the muscles that move the arms with power sufficient to agitate the machines adapted to them.

In concluding this abridgment of animal mechanism, it only remains for me to speak of the manner in which walking is modified in ascending or descending a hill; of throwing a movable body; of pushing it from, or drawing it towards us, &c. &c.; of the varieties of motion in quadrupeds that walk, run, jump, climb, and frisk about; and, finally, of the mode of progression peculiar to serpents and slow reptiles. These minutiæ, too diffusive for a work of this kind, are to be found treated, *ex professo*, on this important part of physiology, the only point in which objects of demonstration can be carried to a degree of mathematical certainty, which is sought after with so much avidity by every man of solid reasoning and correct judgment.

Consult Borelli, *De Motu Animalium*, in 4to. The errors contained in this work are in consequence of the author being a better mathematician than anatomist.

P. J. Barthez, *Nouvelle Méchanique des Mouvemens de l'Homme et des Animaux*, in 4to.

CHAPTER IX.

VOICE AND SPEECH.

CXXXIX. THE voice is a sound resulting from the vibrations which the air suffers during its passage through the glottis when expelled from the lungs: from this sound, articulated by the motions of the tongue, lips, and other parts of the mouth, speech is produced, which may be defined *an articulated voice.*

All animals possessed of a pulmonary organ have voice, for the production of which, air must be accumulated in any receptacle, forcibly expelled in a volume, and meet with elastic and vibrating parts in its passage. Fish, as they have only gills, cannot produce any sound; but this disadvantage, which is certainly inimical to their mutual intercourse, is partly compensated by the extreme velocity of their motions.

The larynx, a kind of cartilaginous box situated at the superior part of the trachea, is the instrument of the voice. The delicate and elastic cartilages that constitute its parietes are united together by membranes and several small muscles. Three of the five cartilages only take an active part in the production of the voice: these are the arytenoid and the thyroid. The only use of the epiglottis is to close the entrance of the larynx, and thus obviate the descent of food into the trachea and lungs; while the cricoid, situated at the inferior part of the organ, serves as a base on which the arytenoid and cricoid cartilages perform motions, by which the aperture of the glottis is increased or diminished for the formation of grave or acute sounds.

This opening, in an adult ten or eleven lines long, and two broad at its greatest diameter, is the most essential part of the larynx; it is, in fact, the true organ of the voice, which is totally mute when the trachea or larynx is laid open below it, and the air prevented from passing through. When the opening is made above the part occupied by the glottis, speech only is lost; which proves that the voice and speech are two distinct phenomena, one taking place in the larynx, the other resulting from the action of the different parts of the mouth, and particularly of the lips.

Do the different modifications of which the voice is susceptible depend on the largeness or smallness of the glottis, or on the tension and relaxation of the ligaments that form the sides of this aperture? Should we coincide with Dodart in considering the larynx a wind-instrument, or adopt the opinion of Ferrein, who views it in the light of an instrument with strings?

It is very certain that the voice becomes stronger, and passes from acute to grave in proportion as the glottis enlarges by advance of age; that it always remains more acute in women, whose glottis is smaller by one third than in man. But do not the tension or relaxation of the ligaments that constitute the sides of the glottis (the vocal chords of Ferrein) render these ligaments susceptible of executing, in a given time, vibrations more or less extensive and rapid? so that if the air expelled by expiration from the lungs strike them during the state of tension produced by the action of the posterior crico-arytenoid muscles which carry back the arytenoid cartilages, and to which are attached the ligaments of the glottis, while the thyroid, attached to the other extremity of the same ligament, is carried forwards by a kind of curve, occasioned by the action of muscles that pass from this cartilage to the cricoid (crico-thyroidei); the voice will be acute, that is, clear and piercing, instead of which it would be grave if the arytenoid cartilages, being carried forwards by the action of the lateral crico-arytenoid and thyro-arytenoid muscles, the vocal chords were relaxed, and vibrated less frequently.

The arytenoid muscle serves for the production of acute sounds, by approximating both arytenoid cartilages.

It has been objected to the theory of Ferrein, that to perform the office of vibrating chords, the ligaments of the glottis are neither dry, stretched, nor isolated; a triple condition necessary for the production of sound in those instruments, to which this anatomist has compared the larynx: but although the ligaments of the glottis do not perfectly resemble chords, they are analogous to vibrating bodies placed at the top of wind-instruments, as the reed in hautboys, the mouth-piece in flutes, and the lips in the horn, and equally contribute to the formation and varied inflexions of vocal sound; besides, it is so much more difficult entirely to reject their influence, as the state of tension always coincides with the narrowness of the glottis; and as both these conditions produce the same effect, it is difficult to decide whether it is to be attributed to one rather than to the other, so is it impossible to determine whether it be on the width of the aperture, or relaxation of ligaments, that grave sounds depend. A subsequent reason, that induces me to consider the larynx as performing the part of a wind and chord instrument at the same time, is, that the ligature or section of the recurrent nerves, which convey to these muscles the power of contraction, occasions an absolute privation of voice, which evidently proves the necessity of some action in the sides of the orifice.

The modifications of voice depend not only on the varied size of the opening of the glottis and of the tension of its ligaments, but also on the length of the trachea. A singer, who wishes to run through the whole gamut by passing from the upper to the lower notes, evidently shortens the neck and trachea, but, *vice versâ*, lengthens them to produce a contrary effect.

The strength of the voice depends on the volume of air that can be expelled from the lungs, and on the greater or less power of vibration (*vibratility*) of which the parietes of the canals are possessed in passing outwards. Birds, the body of which is mostly aërial, have a voice very strong when compared to their size; their trachea, provided with a double larynx (consult Cuvier's Memoirs on the double Larynx and Voice of Birds), is almost entirely cartilaginous, particularly in certain chattering birds, as the jay and some others; while it is nearly membranous in the hedgehog, a small quadruped, the noise of which is almost imperceptible.

The hissing of serpents and the croaking of frogs may be heard at some distance, because these reptiles can expel a great quantity of air from their vesicular lungs; and in the latter the vocal chords are completely isolated from the parietes of the larynx, with which in other animals they are intimately connected.

The voice of man is stronger in proportion to the extent of capacity of the thorax; it always becomes weaker after meals, when the stomach and intestines, distended by food, push up the diaphragm, and constitute an obstacle to its descent. The voice, formed in the passage of the air through the glottis, acquires more force and intensity, becomes much more sonorous by the reflections which it suffers in the mouth and in the nasal canals. It becomes weaker and disagreeably altered when a polypus of the nasal fossæ or of the throat, or destruction of the ossa palati, prevent the air from passing into the nasal fossæ and their different sinuses; it is then said that persons speak through the nose, although, on the contrary, this change of voice depends on its not having been modified in the different cavities which connect with the nose.

Speech.

CXL. To speak in a low voice or whisper, is to articulate very weak sounds, which, in fact, do not deserve the name of voice, since they do not exceed the noise of the air in expiration. Man alone can articulate sounds, and possesses the gift of speech: the particular disposition of the mouth, tongue, and lips in quadrupeds, renders pronunciation impossible. The ape, in which these parts are formed as in man, would speak like him, if the air, in passing out of the larynx, did not rush into the hyothyroid sacs, in some animals membranous, but cartilaginous in others, and even osseous in the alouette or purr, whose howl is so hoarse and frightful. Every time the animal wishes to cry these sacs become distended, then emptied, so that it cannot furnish the different parts of the mouth with sounds to be articulated, (a structure analogous to this is observed in the ass).

Articulated sounds are represented by letters that express all their power: it will be admitted without much reflection, how great a step man made towards perfection when he invented these signs, adapted to preserve and transmit his thoughts. Sounds are expressed by the letters called *vowels*, which mean letters that the voice gives nearly formed, and which only require a greater or less aperture of the mouth, by separating the maxillæ and lips to produce articulation. We easily pronounce the letters, a, e, i, o, u; these are the first that the child utters; besides, they seem to require less study than *consonants:* the latter, which form the most numerous class of letters in the alphabet, only serve to connect the vowels, as implied by their name: the pronunciation of them is always less natural, and consequently more difficult. It is therefore observed that the most harmonious languages, and the words of which strike the ear most agreeably, are those which consist in a greater number of vowels and fewer consonants. It is chiefly on account of this advantage that the Greek has an ascendency over all other languages, ancient and modern;

> —*Graii*——*quibus dedit ore rotundo*
> *Musa loqui.* HORAT.

that among the dead languages the Latin holds a second rank; and that the Russian, Italian, and Spanish have a more agreeable pronunciation than the French; and particularly than all the idioms derived from the *Teutonic*, as the English, German (it would be difficult to accumulate a greater number of consonants in one word than is found in the proper name of a German called Schmidtgen), Dutch, Swedish, Danish, &c. In some people of the North all these articulated sounds seem to pass out of the nose or throat, and form an unpleasant pronunciation; doubtless, because, from requiring more efforts, he who listens participates in the fatigue that seems to be suffered by him who speaks.

It was not considered sufficient to distinguish letters into vowels and consonants; other classes have been established according to the parts which are more particularly employed in their pronunciation; we therefore find labial, oral, nasal, and lingual, and the semi-vowels M, N, R, L, which have different names, from the tongue, in articulation, coming into contact with the arch of the palate, the teeth, or lips. There are likewise consonants explosive, as K, T, Q, G, D, B, P; and hissing, H, X, Z, S, J, V, F, C, which are more numerous, and more frequently employed than in languages of which the pronunciation is most difficult. If a knowledge of this subject were of direct utility, the mechanism of pronunciation of every letter of the alphabet might be explained at the risk of furnishing a new scene to the *Bourgeois Gentilhomme*.

Singing, Stammering, Dumbness, Ventriloquism.

CXLI. Singing is nothing more than the voice modulated; that is, running through the different degrees of the harmonic scale with more or less rapidity, passing from grave to acute, and from acute to grave sounds, likewise expressing the intermediate notes. Although most generally our *song* may be *spoken*, speech is not necessary. This action of the organs of voice requires more efforts and motion than speech; the glottis enlarges or contracts, the larynx is elevated or depressed, the neck elongates or shortens itself; inspirations are accelerated, prolonged, or retarded; expirations are long, or short and abrupt. Thus all these parts are more fatigued than during speech, and it is impossible to sing for so long a time as we speak.

Notwithstanding what Rousseau has said on this subject in his Dictionary of Music, singing may be considered the most natural expression of the passions of the mind, since the less civilized people express different sentiments that agitate them by songs of war, love, joy, or sorrow; and as each affection of the mind modifies the voice in a certain manner, music, which is merely an imitation of singing, can, by the assistance of its notes, depict love or fury, sorrow or joy, fear or desire; it can produce the emotion that these different states occasion, govern the course of our ideas, direct the operations of the understanding, and the acts of volition. (Read Gretry's *Essais sur la Musique*, &c.) Of all the instruments employed in this art, the vocal organ of man is beyond controversy the most perfect; it is that from which may be obtained the most agreeable and most varied combinations. Who is unacquainted with the peculiar property of the human voice to adapt itself to all accents, and to imitate every language?

See in *Aviceptologie Française*, or the art of taking all kinds of birds, the manner in which they are allured into snares by counterfeiting their notes.

The agreeableness, the justness of the voice, the extent and variety of inflections of which it is capable, depend on the correct conformation of its organs, on the flexibility of the glottis, elasticity of its cartilages, and particular disposition of the different parts of the mouth and nasal passages, &c. If the two halves of the larynx or nasal fossæ be unequally distributed, it is sufficient to occasion a defect of precision and neatness of the voice.

Stammering. This is a corruption of pronunciation too well known to require a definition. A tongue too large and thick; a considerable diminution of irritability, as in ebriety, in the commencement of apoplexy, or certain fevers of a bad type; an unusual length of the frenum of the tongue, by impeding the facility of its motions, become causes of stammering: it may likewise be produced by the deficiency or bad arrangement of several teeth. The same causes, but particularly the length of the frenum of the tongue, retain this organ about the inferior parietes of the mouth, and prevent its apex from striking the anterior part of the roof of the mouth, so as to pronounce the letter R: this defect of speech is called *lisping*.

As to *dumbness*, it may be *accidental*, or from *birth*. When by any accident, as a gun-shot wound, a cancerous tumour that has required extirpation of a portion of the tongue, a part of this organ is destroyed, so that it can be no longer made to come into contact with different parts of the parietes of the mouth, and combine its motions with those of the lips; such persons are then *dumb*, that is, deprived of speech; they still preserve the voice or the faculties of uttering sounds, and may even articulate them by mechanically adjusting those parts of the tongue, lips, or palate, the defect of which had impeded pronunciation.

This is not the case in dumbness from birth. Very often these parts of the mouth do not present any state of malformation, and still the infant will not be able to speak: such is the fact in a boy about three years and a half old, that was brought for me to perform the operation of dividing the frenum of the tongue. Sometimes, however, the tongue adheres too firmly to the inferior parietes of the mouth, because the internal membrane of this cavity is reflected over its superior surface before it has passed to the line of division on its inferior surface: in other subjects the edges of the tongue adhere to the gums.

It has happened that the tongue may have been paralytic: such was the case of the son of Crœsus, the surprising history of which is related by Herodotus.

In those who are deaf and dumb from birth, the dumbness has deafness always as its cause: this is, at least, agreeable to the constant observation of Sicard on the great number of pupils committed to his charge, which has induced him to affirm that the absence of speech in them does not so much deserve the name of dumbness as of silence. It is to be entirely attributed to the absolute ignorance of sounds, and of their representative value in letters of the alphabet. The organs of the voice offer no visible traces of injury; they are very apt in themselves to fulfil the uses for which nature has destined them, but they remain in a state of inaction, because the deaf infant is not conscious that he has the means of communicating his thoughts.

It is from this ingenious theory that M. Sicard has perfected the artificial alphabet of Peirere, by the assistance of which he has been able to succeed in causing deaf and dumb persons to articulate a great number of vowels and consonants, to compare words and sentences. (See his Grammar for the Use of the Deaf and Dumb, which is also useful to those who hear and speak.)

To teach a deaf and dumb person how the letters of this new alphabet are pronounced, he is enjoined to study the motions of the lips and those of the larynx; and changing his whole body into an instrument of harmony by an ingenious combination, his arm is used to regulate the strong or weak inflections of certain sounds in the same manner as the action of pedals is employed to modify the touches of a *forte-piano*.

> It is known that old men, when deaf from advanced age, pay great attention to the motions of the lips, the different expressions of the countenance, and, by this attentive observation, form some conjecture of the thoughts.

But it is principally by means of the organ of sight that instruction is conveyed to those who are born deaf and dumb: a manual alphabet, that is, the letters of which are expressed in drawing them by varied positions of the fingers, is the medium that is most readily employed to make them understand. By this *dactyologic* process the transmission of ideas is effected with a rapidity that surprises such as have never before witnessed its execution.

To conclude this chapter, it only remains for me to mention a phenomenon, which, by its singularity, is worthy of the attention of physiologists; it is known by the name of *ventriloquism*, and those who possess it are called *ventriloquists*, because their voice, which is always weak and not very sonorous, seems to come from the stomach. There resides in the ci-devant Palais Royal, in the coffee-house of the Grotto, a man who can maintain a dialogue with such accuracy, that we should be induced to believe two persons were actually engaged in conversation at a certain distance from each other, the accent and voice of whom seem to be entirely different. I have observed that he does not inspire when speaking from the belly, but that the air passes in smaller quantity from the mouth and nostrils than when in ordinary speech. Every time that he exerts this unusual peculiarity he suffers distention in the epigastric region; sometimes he perceives the wind rolling even lower, and cannot long continue this exertion without fatigue.

At first I had conjectured that a great portion of the air expelled by expiration did not pass out by the mouth and nostrils, but was swallowed and carried into the stomach, reflected in some part of the digestive canal, and gave rise to a real echo; but having afterwards more attentively observed this curious phenomenon in M. Fitz-James, who represents it in its greatest perfection, I was enabled to convince myself that the name *ventriloquism* is by no means applicable, since the whole of its mechanism consists in a slow, gradual expiration, drawn in such a way that the artist either makes use of the influence exerted by volition over the muscles of the parietes of the thorax, or that he keeps the epiglottis down by the base of the tongue, the apex of which is not carried beyond the dental arches.

He always makes a strong inspiration just before this long expiration, and thus conveys a considerable mass of air into the lungs, the exit of which he afterwards manages with such address. Therefore repletion of the stomach greatly incommodes the talent of M. Fitz-James, by preventing the diaphragm from descending sufficiently to admit of a dilatation of the thorax, in proportion to the quantity of air that the lungs should receive. By accelerating or retarding the exit of air, he can imitate different voices, and induce his auditors to a belief that the interlocutors of a dialogue, which is kept up by himself alone, are placed at different distances; and this illusion is the more complete in proportion to the perfection of his peculiar talent. No man possesses to such a degree as M. Fitz-James the art of deceiving persons who are least liable to delusion: he can carry his execution to five or six different tones, pass rapidly from one to another, as he does when representing an animated dispute in the midst of a popular assembly. I have often heard him repeat the parts which he represents in Robertson's Phantasmagoria, where his comic and familiar exertions greatly add to the illusions represented.

CHAPTER X.

GENERATION.

The Difference of Sexes.

CXLII. THE functions which constitute the object of this chapter are not necessary for the life of the individual; but without them the human race would soon perish if deprived of the faculty of reproducing itself. These functions preservative of the species are intrusted to two orders of organs belonging to both sexes, of which they form the principal, but not the only difference.

Woman, in fact, not only differs from man in her genital organs, but also by a shorter stature, a delicacy of organization, and a predominancy of the lymphatic and cellular systems that obliterate the projection of muscles, and invest all her limbs with those rounded and graceful forms, of which the Venus de Medicis is an inimitable model. She is likewise distinguished by a more lively sensibility, joined to less strength and greater mobility: her skeleton even presents differences sufficiently obvious to render it distinguishable from that of man; the asperities of bones are much less marked, the clavicle is less curved, the thorax shorter and wider, the sternum shorter and broader; the pelvis larger, the thigh bones more oblique, &c.

Compare the fine plates of Albinus and Sœmmering, of the male and female skeleton. In a lecture on mathematical beauty, &c. delivered by Professor Camper in the Academy of Drawing at Amsterdam, this celebrated physiologist has proved, that in tracing the figures of the body of the male and female in two imaginary ellipses of equal dimensions, a portion of the pelvis of the latter would be out of the ellipsis, and her shoulders within it, while in the former the shoulders would project beyond the limits of the figure, and his pelvis, on the contrary, would be entirely inclosed within it.

The general characters of the sexes are so marked, that a male can be distinguished by seeing a part of his body uncovered, although this part were not covered with hair, nor offered any of the principal attributes of virility. Should this variety of organization and character be referred to the influence which the sexual organs exert over the rest of the body? Does the uterus impress the sex with all its distinctive modifications? and can we say with Van Helmont, *Propter solum uterum mulier est, id quod est*—It is in consequence of the uterus only that woman is what she is? Although this viscus may react on all the female system in a very evident manner, and seem to have an influence over almost the whole of the actions and affections of woman, we are of opinion that it is not the only cause of the characters by which she is distinguished, since these characteristics are cognisable in the early part of life, when the uterine system is far from being in a state of activity. A very curious observation of Cailliot's, in the second volume of the Medical Society of Paris, proves much better than all reasoning that could be adduced, to what extent the characters of sex are independent of the uterus. A woman is born, and grows up with all the external appearances of her sex; when advanced to the age of twenty or twenty-one years, she wishes to satisfy the desire of nature: vain desires! useless efforts! She had nothing farther than the vulva properly formed; a small canal, about two lines in diameter, occupy the place of the vagina, and terminated in a cul-de-sac an inch in depth. The most attentive examinations made by introducing a catheter into the bladder, and the index into the rectum, could not find an uterus:

the finger passed into the intestine distinctly felt the convexity of the instrument in the bladder; so that it was evident that no organ analogous to the uterus separated the fundus of this viscus from the parietes of the rectum. The young female had never been subject to the periodical evacuation that accompanies or precedes puberty; no hæmorrhage had supplied the place of this excretion; she did not perceive any of those indispositions which the non-appearance of the menses occasions; she enjoyed, on the contrary, robust health: nothing of the other characters of her sex was deficient; her breasts were rather small.

We shall not proceed farther in the examination of the general differences that characterize both sexes; no person has so well investigated this subject, nor treated it in a more scientific manner than M. Roussel, in that excellent work, *Systéme physique et moral de la Femme.*

Hermaphrodism.

CXLIII. Hermaphrodism, or the union of both sexes in the same individual, is impossible in man and in the numerous class of animals of red blood: collections of observations present no well-attested example, and all hermaphrodites that have been hitherto seen were malformed beings, whose male organs were imperfect, or the female apparatus too prominent, so as to render the sex doubtful. No one has shown himself capable of impregnating his own person, so as to produce a being like himself; the greater number were unable to assist in the reproduction: an imperfection or ill conformation of the organs employed for such purpose condemned them to sterility. This was the case of the hermaphrodite mentioned by Petit of Namur, in the Memoirs of the Academy of Sciences, and of that of which Maret has given the history in the Transactions of the Academy at Dijon, and all those observations on this subject found in the Memoirs of the Medical Society, which contains the greatest number of these facts.

But if complete hermaphrodism has never existed in man and in all beings, the organization of which is most analogous to his own, numerous examples are to be found in animals of white blood, and particularly in plants that are in the lowest part of the organized scale: polypi, several worms, oysters, and snails, are likewise subject to this peculiarity. The latter reptile presents a very particular variety of hermaphrodism, because its male and female organs are united in the same individual; yet it is not susceptible of generation alone, but requires to be coupled with another individual equally hermaphrodite, in order to be stimulated by friction, and other means of irritation, to the act for its own reproduction.

The immense tribe of monöic plants offers an example of the male and female organs on the same stalk, and mostly on the same flower. Numerous stamina surround one or more pistils, spread on the stigma their fecundating dust, *pollen*, which is carried to the ovarium by the canal of the stylum, to fecundate those grains by means of which the species is perpetuated.

Sometimes the sexes are separated by a considerable space; the seminal powder is then carried from the male to the female by the wind: palm-trees (from which Gleditsch made his first observations on the generation of plants), flax, spinage, mercurialis, &c. are thus formed.

CXLIV. Man presents a peculiarity in not being subject to the influence of the seasons in the exercise of his genital functions; animals, on the contrary, cohabit at fixed periods and certain times of the year, and afterwards seem to forget the pleasures of love to satisfy other wants: thus wolves and foxes couple in the winter, deer in the autumn, the generality of birds in the spring, &c.; man alone has sexual intercourse at all times, and impregnates the female under every latitude and in all climates. This prerogative is perhaps less to be attributed to his particular nature than to the advantages resulting from his industry; sheltered from the rigours of the season and variations of the atmosphere, by the abode which he has been able to construct, and having it in his power to satisfy his physical wants by means of provision, which his foresight had accumulated, he can at all times, and under equal advantages, partake of the enjoyments of love. Domestic animals, that we have in some measure abstracted from external influence, are productive almost indifferently in all seasons. To prove this still better, it is by the resources of his industry that the powers of nature are neutralized, and that man has arrived to a degree of independence in the act of reproducing his species, so far as may be dependent on the seasons. It may be observed that this influence of temperature is so much the more strongly marked, in proportion to the distance of gradations in those animals from man; that on this principle the spawn of fish and frogs is accelerated or retarded according to the early or late appearance of the season; and that a great number of insects require for their reproduction a certain degree of heat, the absence of which prevents them from existing.

The Organs of Generation in Man.

CXLV. Aristotle, Galen, and their verbose commentators, have expressed the analogy that exists between the genital parts of both sexes, by saying that they only differed in situation, being external in man, and internal in woman. In fact, there is some resemblance between the ovaria and testicles, the Fallopian tubes and vasa deferentia, the uterus and the vesiculæ seminales, the vagina (the external parts of generation in the female) and the penis: the first secrete the seminal fluid, and supply, both in the male and female, a liquor essential to generation (*ovaria* and *testicles*): the Fallopian tubes, as well as the vasa deferentia, carry this liquor into reservoirs, where it is to remain (*uterus* and *vesiculæ*). These contractile receptacles, which serve to contain the semen or its production, expel it after retaining it for some time; and, lastly, the vagina and penis are employed for its elimination. However near these coincidences may appear, we should be far from asserting the existence of a perfect similitude between the genital apparatus of both sexes; each of them performs functions perfectly distinct, though reciprocally essential in the act of reproduction.

> "*Ut virilia ad dandum, sic muliebria ad recipiendum a natura apta sunt*, &c." Ch. Crève.

CXLVI. The prolific liquor is secreted by the testicles, two bodies enveloped in several coverings, one of which, formed by the cutis, and known by the name of *scrotum*, represents a sac common to both, contracts by cold, relaxes by heat, and possesses a degree of contractility more evident than other parts of the cutaneous structure. The *dartos* forms a second cellular covering to each testicle; the tunica vaginalis, a serous membrane, constitutes their immediate covering, and reflects itself over their surface in the same manner as the peritoneum is expanded over the abdominal viscera; that is, it does not contain them in its proper cavity; and, lastly, the testicles are invested by a fibrous, white, thick, and condensed membrane, which forms part of their substance, and is called *albuginea*, from the internal surface of which pass off a great number of membranous laminæ, that by intersections in its cavity form a number of cells filled with a vascular, yellowish substance. This filamentous matter inclosed in the albuginea is so thin that it would soon dissolve if the testicle were deprived of its external covering; it is formed by seminiferous ducts, small tubes, truly capillary, contorted and folded in a peculiar manner, arising probably from the extremities of the spermatic arteries passing towards the superior part of the oval represented by the testicles, uniting in this point, and forming ten or twelve canals collected into a fasciculus, constitute a chord in the substance of the tunica albuginea, called the body of Highmore. This chord perforates the membrane, in the substance of which it was contained, and the whole of the ducts unite into one canal, contorted upon itself, and forming an eminence called the head of the *epididymis*, which, in its progression towards the inferior extremity of the testicle, becomes less convoluted, and taking the name of vas deferens, ascends with the spermatic chord to the abdominal ring, through which it passes into the abdomen. The vasa deferentia, though equal in thickness to a quill, have a very small cavity; and it is difficult to explain why so narrow a tube should possess an hardness approaching to cartilage.

The semen is eliminated by the testicles, and separated from the blood carried thither by the spermatic arteries, which are long, slender, tortuous, and pass from the aorta in an acute angle: this liquid goes through the seminiferous ducts into the *corpora* of Highmore, and ultimately into the *vasa deferentia*, which, after entering the cavity of the abdomen, terminate in the vesiculæ seminales, and there deposit the spermatic liquor. The delicacy of the organization of the testicle, the tenuity of the vessels through which the semen passes, explain the facility of its obstructions.

The spermatic liquor flows from the vasa deferentia into the vesiculæ, notwithstanding the retrograde angle by which they are connected: these sacs for the reception of the semen are under circumstances similar to the gall-bladder. Notwithstanding the obtuse angle of communication between the vas deferens and vesiculæ seminales, the fluid passes from the former into the latter; the bile follows that direction, because the ductus choledochus is pressed by the coats of the duodenum, and collapsed when empty; the semen takes that course, for the ductus ejaculatorius passes through the prostate, and opens by a small orifice into the urethra; this liquid, therefore, flows more easily from the vas deferens into the vesiculæ seminales than into the ejaculatory duct.

The *vesiculæ seminales* form two distinct pouches of variable capacity in different individuals, larger in youth and adults than in infancy and old age; their internal structure is divided into several cells or alveolæ, lined by a mucous membrane that secretes a considerable quantity of a glairy humour, which mixes with the semen, forms its greater part, and serves for its vehicle. The situation of the vesiculæ seminales between the rectum, levator muscles of the anus, and body of the bladder, causes their excretion, which is chiefly dependent on the tonic action of their parietes, to be likewise assisted by slight compression from the levatores ani, thrown into convulsion at the moment of ejaculation. Animals destitute of this seminal reservoir, dogs, for example, remain for a long time in sexual contact, as the prolific liquor necessary to fecundation must be elaborated during the time of copulation, and can only flow drop by drop.

The *ductus ejaculatorii*, which are formed by the connexion of the *vasa deferentia* with the *vesiculæ seminales*, pass through the prostate gland, and have separate apertures in the urethra at the bottom of a lacuna, called *verumontanum*. The glandulous body in which they are inclosed, and which supports both the neck of the bladder and beginning of the urethra, does not exist in the female: ten or twelve ducts convey into the urethra the mucous, whitish liquid secreted by the prostate. The prostatic fluid mixes with the semen, and augments its quantity; perhaps also by being thrown out first it lubricates the internal surface of the canal, and thus prepares the passage for the emission of the seminal liquor.

The urethra is not only employed to carry the semen out of the body, but serves likewise as an excretory duct for the urine, and constitutes a portion of the penis; which organ, being destined to convey the prolific liquor into the genital parts of the female, requires to be in a state of erection to perform that function with convenience; and as this state should be considered a phenomenon of structure, it will not be explained until the female parts of generation have been described.

The Organs of Generation in Woman.

CXLVII. We shall not adopt the anatomical order generally followed in this description; but by arranging under a triple division the different parts which perform the genital functions in woman, we shall first speak of the ovaria and Fallopian tubes, then of the uterus, and, lastly, of the vagina and external parts.

The *ovarium*, situated in the pelvis of the female, and connected to the uterus by a ligament, receives the vessels and nerves which go to the testicle in the male; it has even the form of this organ, though generally smaller. Does the ovarium secrete a liquor, that, mixing with the semen of the male, produces the new being? or is there detached from it at the moment of conception an ovum which is vivified by the semen? Whatever part be taken in this discussion, we shall be forced to admit that the ovarium prepares something essential to generation, since its removal renders the female steril.

It is doubtless likewise that this something, furnished by the ovaria, passes through the Fallopian tubes into the uterus, which receives one of their extremities, while the other, large, expanded, and fringed at its margin, floats in the cavity of the pelvis, supported by a small duplicature of the peritoneum, but contracts on itself, is closely applied to the ovarium during coition, and then constitutes a direct channel between this organ and the internal part of the uterus. The external orifice of the Fallopian tube, or its fringed parts, has been found closely investing the ovarium in certain females opened immediately after copulation. It may happen that the Fallopian tube, from some organic defect, cannot embrace the ovarium. In dissecting a subject at *La Charité* that had been steril, I found the fringed margins, or expanded extremities of the tubes, adhering to the lateral and superior parts of the pelvis, so that it had been impossible for them to perform the motions necessary for fecundation.

The uterus, or womb, situated in the pelvis, between the rectum and bladder, is an hollow viscus, in which the produce of conception grows and is developed until the period of parturition; its internal cavity has been found divided into two portions, which, in some instances, have been connected by one vagina; in others there has been detected a distinct vagina to each, or double only in that part nearest to the uterus. Valisnieri, indeed, mentions a woman who had two uteri; one connected with the vagina, in the usual manner, and another that communicated with the rectum. Although the muscular nature of the parietes of the womb is evidently distinguishable during the advance of pregnancy, yet it may be said that this hollow muscle differs from other organs of this species by the arrangement of its fibres, which it is difficult to perceive when its cavity is empty, and impossible to demonstrate when distended by the fœtus; but this part is most particularly distinguished by the singular property it possesses of dilating, and becoming augmented instead of diminished in thickness.

The *vagina* has nothing remarkable but the soft, rugous, and dilatable structure of its parietes. The superior extremity of this oblique canal, directed backwards and upwards, embraces the neck of the womb; but its inferior orifice is surrounded by a spongy body, the cells of which are occasionally distended with blood, like the *corpora cavernosa* of the penis and clitoris. This is called *plexus retiformis;* its distention during erection can contract the entrance of the vagina; the contractions of the constrictor muscle, which is similar to the *erector penis* in man, by being situated on the retiform plexus, also surrounds the entrance of the vagina, and may likewise render that part narrower.

Besides, this external orifice, in females that have not had sexual intercourse, is furnished with a membranous fold of various extent, generally semicircular, and known by the name of *hymen:* its existence is mentioned by several physiologists as the most certain sign of virginity; but all the characters that have been considered capable of proving its existence, and which men have so ardently desired to possess, offers nothing but what may be deemed equivocal. The laxity of parts, lubricated by a considerable quantity of mucus in women subject to the *leucorrhœa*, or by the blood during menstruation, may have caused the hymen to yield without breaking; and a woman who has absolutely lost her virginity may still seem to be a virgin, while another, perfectly chaste, shall have lost her hymen by a disease, &c. In fact, there are individuals in whom this membranous fold is so little evident, that some anatomists have almost doubted of its existence.

The other external parts of generation, which are easily examined without dissection, should not be considered merely as convenient; all of them will be found to fulfil some useful purpose. The folds of the skin forming the large and small labia are of great importance in parturition, and facilitate dilatation necessary for the expulsion of the fœtus: these duplicatures not only unfold at this period, but are considerably expanded in their texture, which is softer and more extensible than that of the skin. The mons veneris, the hair, and the clitoris, which imperfectly resembles the penis, seem to be only organs of pleasure. But is not pleasure itself to be considered as an element in the act by which the human species is perpetuated?

Conception.

CXLVIII. When any irritation, either chemical, mechanical, or mental, solicits the action of the genital organs, the penis becomes elongated, swelled, and rigid, by an accumulation of blood in the cells of the corpora cavernosa, and in the structure of the corpus spongiosum of the urethra. —"*Penis adest, ità constructus, ut stimulo corporeo, sive mentali irritatus, turgeat et obrigescat, seque erigat posteà detumescat, et collabatur.*" Crève. A turgescence of both these parts of the penis should take place at the same time for the erection to be perfect. This phenomenon has been attempted to be explained by the compression of the pudical veins, by being situated between the symphysis of the pubis and root of the penis, and during erection pressed against these bones by the muscles that elevate it: but the muscles of the perineum, particularly the ischio-cavernosus, have a tendency to draw it downwards. The blood that distends the corpora cavernosa, corpus spongiosum of the urethra, and glans penis, which is only an expansion of the latter structure, does not stagnate in the cells, but is only there in greater abundance than usual, in consequence of the action of arteries conveying blood to those parts, being increased by irritation. The erection, which is always proportionable to the vivacity of the stimulus, ceases when the irritating cause no longer acts on the penis, in the same manner as an inflammatory tumour is dissipated or resolved when the cause of determination is removed (see the preliminary observations). In this libidinous dilatation, the urethra, drawn by the penis in elongating, becomes straight, its curvatures are obliterated, the irritation is conveyed from the external to internal parts, as far as the vesiculæ seminales and testicles, which swell, and then have a more active secretion: they are lightly agitated by the tonic action of the scrotum, which becomes corrugated, and carries them towards the abdomen, and by the contractions of the fibres of the cremaster muscle, the expansion of which, between the tunica vaginalis and dartos, has been improperly called *erythroïdes*, they empty themselves with greater facility into the vasa deferentia, there become shorter by the ascent of the testicles, and participate in the agitations suffered by these organs. When the irritation is increased to a certain degree, it is conveyed to the vesiculæ seminales; these act upon the liquid that distends their cavity, and expel it by the spasmodic contraction of their membranous parietes, assisted in this excretion by the levator muscles of the anus (CXLVI.). The prostate and mucous glands of the urethra furnish a viscous substance, proper to facilitate the ejection of the seminal liquor, propelled by jets with more or less impetus.

CXLIX. The human semen is never evacuated pure, that is, such as it has been prepared by the testicles; it is even conjectured that the mucous liquor of the vesicles forms a very considerable part. It is this mucus which is evacuated by eunuchs in great quantity. The liquor of the prostate, and that furnished by the mucous glands of the urethra, likewise effect some change upon it by their admixture.

When received into a vessel it exhales a peculiar odour, analogous to that of the pollen of a great number of vegetables; for example, the rough part of the chesnut-tree. It is formed of two parts, one of which is thick and grumous, the other viscid, white, and more fluid. The proportion of the fluid to the viscous part is greater according to the debility of the individual, and the frequency of emission: it soon liquefies, and becomes specifically lighter, though always heavier than water, in which it is then soluble, but not so at the time of ejection. When analyzed by Vauquelin, it exhibited $\frac{90}{100}$ of water, 6 of animal mucilage, 3 of phosphat of lime, and 1 of soda: it is in consequence of this alkali, that it changes the sirup of violets green. The animal mucilage is not pure albumen; it should be rather considered a gelatinous mucus, on which the qualities of the semen seem to depend, as its indissolubility in water, its odour, and spontaneous liquefaction.

The semen, when examined by a microscope, exhibits animalcula with a round head and slender tail, that move with rapidity. Should the liquefaction of the viscid and filamentous parts of the semen be attributed to their motions? These microscopic animalcula are not found in the semen till the period of puberty: some anatomists have thought that they avoided the light, and have even described their habits and diseases. The imagination has had great influence over every thing that naturalists have believed they discovered in these little animals, and in the mechanism of their reproduction: besides all the animal humours, the juices of a great number of plants present more or less of these animalcula when viewed in the microscope.

There is not only a spasmodic affection in the organs of generation to effect an expulsion of the semen, but the whole body participates in this convulsive state, and the instant of ejaculation is marked by an orgasm through every part; so that it seems, says Bordeu, that nature has forgot for the moment every other function, and is totally occupied in collecting her powers and directing them towards the same organ: an universal languor follows this general convulsion. To this state of corporeal lassitude, is joined a state of sadness and melancholy, which has its comforts. Does this particular sensation, which caused Lucretius *(De Naturâ Rerum)* to say that sorrow is mingled with the most lively pleasure that we can enjoy, arise from the fatigue of organs; or, as some metaphysicians have believed, from the confused and distant notion which the soul has of its destruction?

The penis does not enter the uterus, although the semen is conveyed into it: the os tincæ is too small, and its thick edges are in contact. It would be even difficult to conceive that this narrow orifice could give passage to the seminal liquid, if we did not know that the uterus, during copulation, is irritated, kept in agitation, and attracts the semen by a real aspiration. Plato compared this organ to an animal existing within another animal, governing all the actions of the living economy, ardently desiring to feed itself on the liquor of the male, and digesting it to form the new individual.

The thickness of the neck of the uterus has been a just cause of doubt, whether its orifice could dilate sufficiently to admit a liquor as thick as the semen; some have therefore believed that this liquid itself did not penetrate into the cavity of the uterus, but its finer and more *spiritualized* part, a prolific liquor that they have called *aura seminalis;* however, the semen has been found in the uteri of animals opened immediately after coition; and Spallanzani, in his experiments on the fecundation of frogs, salamanders, and toads, has proved, that to invest the eggs of these reptiles with the faculty of production, exposing them to the vapour exhaled from the seminal fluid of the male was not sufficient, but, on the contrary, that it was indispensably requisite for the liquid semen to come into immediate contact.

It has been advanced that the uterus, dilated to receive the semen, contracts to retain it; and that this spasmodic contraction of the uterus, perceived (according to Galen) by women who have maintained a sufficient degree of indifference to notice this circumstance, was considered the most certain sign that could be acquired of the fecundity of copulation. It has been, doubtless, with a view to fix this retention, that the custom of sprinkling cold water over certain female domestic animals, that are too desirous of sexual intercourse, has been established.

It has also been observed that women conceive more easily soon after the flowing of the menses, a period in which the neck of the womb is closed with less than usual exactness.

The seminal liquor projected into the cavity of the uterus is carried along the Fallopian tubes; it is not diffused into the cavity of the abdomen, because the membranous canal attaches itself to the ovarium corresponding to it, and establishes an uninterrupted canal from this organ to the uterus: the ovarium, bathed by the semen, and irritated by its contact, gives off a liquor, or a small ovum that passes into the uterus by the same channel that the semen had passed thither. Every thing that remains to be said about the mechanism of generation cannot be advanced as matter of fact, but only as probable, nature has so multiplied her recesses in an operation that so greatly excites our curiosity.

After having distinguished truth from probability, which is indispensable in every science of facts and observations like physiology, we shall advance the hypothesis that seems the most probable on the manner in which the sexes concur in the production of a new being.

CL. Fœtuses pre-exist in the ovaria of females; not that they are to be found there from the creation of the world, agreeably to the opinion of Bonnet, and all who have adopted the system of inclosure of germs; but the ova, which contain these germs, are formed by an action peculiar to the ovaria that secretes them; a new proof that all the phenomena offered by organized bodies, whether the object be a preservation of the species or of individuals, are effected by means of secretions. This ovum, produced by the elaboration of the blood carried to the ovaria by the spermatic vessels, contains the lineaments of the new being; but it is only the outlines, the *cadaver*, if that expression can be admitted, for a body that has never lived. It is requisite that the seminal spirit should be employed to rouse it from this state of inactivity, and to bestow on it, by a kind of electricity, the dawn of life. Eggs laid by an hen that has not yet had intercourse with the cock will never be hatched, although they contain the rudiments of the chicken. If the eggs of a frog be kept from the approaches of the male during the time of spawning, they become putrid in a vessel of water; but on the other hand, if the male has moistened them with his semen at the period of their exit, they will not fail of being produced: their putrefaction may be obviated, and they can be animated by pouring on them the spermatic liquor of the male, collected by the method which Spallanzani used in his admirable experiments on artificial fecundations.

We are principally indebted to the labours of this able investigator for what has been discovered on the mystery of generation, and on the department of each sex in this important function. It is nearly proved that the male only cooperates in furnishing the vivifying principle that is to animate the individuals, the germs of which are produced by the female, and that his part is therefore less essential. In this system it is not so difficult as generally considered, to explain the striking resemblance that so often exists between father and son. The imperceptible embryo has at most the consistence of a jelly a little viscous: a body possessing so little consistency must be very susceptible of impression, and the semen of the male applied to its surface should impress it with powerful modifications. The action of this liquor on the tender embryo is like that of a seal on soft wax, which preserves the impression: this, in the individual, is more strongly marked, and the resemblance more personal in proportion as the male may have assisted in the act of reproduction with a greater degree of vigour and energy.

The seminal liquor of the male can not only act on the surface of the gelatinous and almost fluid germ, and modify its external parts, but may also penetrate by reason of its extreme softness, and impress changes on its internal parts (on this principle may be explained not only the similitude between father and son, but likewise hereditary diseases, or such as are transmitted by means of generation); yet it is known that the internal part seems to be particularly furnished by the female, while the external parts are more influenced by the male, since in the copulation of two animals belonging to different species, the *mule*, a product of this union, resembles the male externally and the female internally. It is difficult to assign the reason of the impossibility of mules to reproduce individuals like themselves. On what account are their sexual parts so well formed, and completely steril? what concealed imperfection neutralizes their action? why do certain hybrids among birds possess the power of perpetuating their race, an advantage that nature has given to some plants, which are real mungrels among vegetables, while she refuses the same things to quadrupeds?

The fecundation of the ovum is effected in the ovarium itself, to which the semen is conveyed as before mentioned. The ovum receives a concussion by the action of the semen and Fallopian tube, detaches itself from the organ in which it was produced, and descends into the uterus by the peristaltic contractions of the tube of Fallopius.

> This canal is susceptible of a retrograde motion. The possibility of it will be conceived, if it be considered that after it has been elongated by a species of erection to convey the semen to the ovarium, by returning on itself it must cause the liquid contained in its cavity to flow in an inverse direction. This retrograde motion, as Nesbit observes, is favoured by the kind of *collapsus* that succeeds the excitement occasioned by the coitus; for Darwin's experiments prove that a debility of vessels is the cause of this mode of action in their parietes.

Extra-uterine impregnations furnish sufficient poof that the circumstances above mentioned take place. If a full-grown fœtus have been found in the ovarium, Fallopian tube, or even in the cavity of the abdomen, when the detached ovum eludes the attractive power of this canal, we shall still be obliged to admit that it usually passes through the course already described. The ovaria, like the testicles, swell and grow at the period of puberty: they lessen, and, in some measure, wither when the woman is no longer able to conceive. One of the ovaria, larger than the other, examined a few days after conception, presents a small yellow vesicle which diminishes during utero-gestation, so that towards the termination of that state there is only to be found a very small cicatrix. It is possible for this vesicle to be the most external covering of the small ovum in which the germ is inclosed, and which may be lacerated to permit its exit?

The observations of Haller prove that the *corpus luteum* is formed by the remains of a vesicle that was ruptured at the moment of conception, and permitted the liquor which it contained to escape. In a sheep opened a few minutes after copulation, on one of the ovaria a vesicle larger than the others was seen: it had been lacerated, and exhibited a small wound, the edges of which were still bleeding. Inflammation takes place in the lacerated parietes of the small sac; granulations arise, and a small cicatrix is formed in the place where the vesiculæ existed: the number of these cicatrices is in proportion to that of fœtuses. It is not known what period of time is required for the detached germ to pass through the tube of Fallopius, and descend into the cavity of the uterus: Valisnieri and Haller have never been able distinctly to find it in the latter viscus before the seventeenth day.

An obstruction of these tubes, as well as a defect or morbid change in the ovaria, may constitute a cause of sterility. Morgagni mentions these tubes in some courtesans having been entirely obliterated by the thickening of their parietes; an evident consequence of the habitual orgasm in which they had been kept by too frequent excitements.

Different Systems of Generation.

CLI. The ancient system of the admixture of the semina in the cavity of the uterus, advanced in the writings of Hippocrates and Galen, is still held in esteem by several physiologists. In this system the mixed fluids may be considered as an extract of every part of the body, both of the male and female: a generative faculty disposes them conveniently for the formation of the new individual.

Every thing that Blumenbach has advanced on the force of power of formation *(nivus formativus)* is relative to this generative faculty: it is only a new term applied to an ancient idea.

M. de Buffon more particularly investigated the facts presumed on the above hypothesis, and has rendered it less probable. According to this eloquent naturalist, each part furnishes its moleculæ or atoms, which he calls organic; and these atoms coming from the eyes, ears, &c. of the man and woman, arrange themselves round the internal mould, the existence of which he admits, believes it to form the base of the edifice, and to arise from the male if it should be a boy, and from the female if a girl. The exercise of our reason prevents us from admitting a theory, in which the formation of the placenta and coverings of the fœtus are not explained; besides, it is contradicted in direct terms by the perfect conformation of infants born of parents, who, if imperfect, or deficient in several organs and members, cannot supply any moleculæ for the formation of those parts represented.

The system of the *ovarists*, which at present is in the greatest esteem, has been preferred by Harvey, Steno, Malpighi, Valisnieri, Duhamel, Nuck, Littre, Swammerdam, Haller, Spallanzani, Bonnet, &c. These men only admit the distinction of animals into oviparous and viviparous, from the latter species being hatched in the body, and breaking their coverings before they come into the world. Lewenhoek, Hartsoëker, Boerhaave, Mery, Werheyen, Cowper, &c. have added to this doctrine of the ovarists, that the semen of the male contains an abundance of spermatic animalculæ, all capable of becoming beings resembling that from which they were formed. These animalculæ pass in a current through the Fallopian tubes to the ovaria, where they enter into a violent contest in which all are killed except one, which being left champion in the field of battle, penetrates into the ovarium destined to receive it. This latter system, very improbable, invests men with the greater part in generation, since the female, according to its authors, only supplies the coverings of the fœtus.

It would be superfluous to treat more diffusively on the opinions advanced on such an abstruse subject; what we have already said is sufficient to prove that the things which most elude the researches of our curiosity, and give greater latitude to the imagination, are those which we believe to know best, and on which we speak with most confidence and prolixity: so true is Condillac's remark, that we have never so much to say as when we set out upon false principles.

Pregnancy.

CLII. A woman, from the moment she has conceived, perceives considerable alteration in the motion of her solids and composition of her fluids. This change is perceptible in all her functions. She exhales a peculiar odour. Sucking children either refuse the breast, or do not take it with avidity, and fall off if they remain long with the nurse.

Nature, attentive to her work, seems to forget every thing to carry it to perfection. It has been observed, that in places where the plague and other contagious diseases are raging, pregnant women are less liable to be affected; but when attacked with such complaints as in other persons, and in themselves at other times, would be without danger, they fall; because these diseases, at first of little consequence, soon acquire a malignant type: the progress of fatal diseases is retarded, and a pregnant woman labouring under phthisis, who, in the usual course of that complaint would soon perish, goes through the regular period of utero-gestation.

The formation of callus in fractures does not require an unusual length of time, although Fabricius Hildanus maintained that the state of pregnancy totally prevented it.

The uterus, after having received the prolific liquor, swells, to use the expression of a modern author, like a lip that has been stung by a bee: it becomes a centre of fluxion, towards which the humours flow in every direction; the diameter of its vessels augments with the thickness of its parietes; the latter become softer, and their muscular nature is perceptible. Pregnancy, till the end of the third month, is only to be discovered by the cessation of menstruation; the uterus is still lying behind the pubis, its neck has not yet experienced any alteration; however, it soon rises above the brim of the pelvis, pushing upwards the intestines and other abdominal viscera. Towards the termination of pregnancy it passes the navel, its fundus touches the arch of the colon, and is sometimes extended as far as the epigastrium: the consequent compression upon the organs of digestion explains the nausea suffered by the female; the derangement of sensibility by the affection of the great sympathetic nerves, also accounts for those depraved appetites, those strange longings which common people think it of so much importance to satisfy. When the term of pregnancy is expired, respiration is impeded, the diaphragm is pushed upwards by the abdominal viscera, and finds some difficulty in descending: thus has nature, as far as possible, obviated this inconvenience by giving the abdomen greater capacity, and diminishing that of the thorax, which is much shorter in the female than in the male subject.

If the growth of the fœtus, its size, the quantity of fluid contained in the membranes, the distention of the uterus, were always equal, the elevation of the latter organ might be defined at any given period of pregnancy: but these conditions are so variable in every individual, that the rules which might be given would be applicable to a small number; we shall therefore only mention extremes. The uterus tends to elevate itself in a vertical direction, and while contained in the pelvis it preserves this direction; but so soon as it has passed beyond the superior margin it is no longer supported, and inclines forwards, backwards, and towards the sides. These inclined positions, when carried to a certain degree, constitute those irregularities of situation which accoucheurs call obliquities of the uterus: their direction is determined by the disposition of parts; it is therefore mostly forwards, either because the superior aperture of the pelvis is naturally thus inclined, and forms an angle with the horizon of 45 degrees; or because the convexity of the lumbar spine pushes the uterus, which is unable to depress the bony arch on the anterior parietes, which yield with greater facility after the woman has been frequently pregnant.

The dilatation of the uterus is not the effect of a mere distention of its parietes; because, instead of becoming thinner as this viscus increases in capacity, on the contrary it augments in thickness by the dilatation of all species of its vessels: in this kind of vegetation the uterus is truly active, and supports itself against the efforts that the fœtus might exert upon it. The neck, which by reason of its greater consistence had resisted the dilatation in the more early state, ultimately relaxes from the influence of the fibres of the fundus over the surrounding parts of the os uteri: the edges of this aperture become thinner, the neck is obliterated, the orifice enlarges, and through it the fœtus may be felt, surrounded by the fluid contained in its membranes.

Towards the end of pregnancy the desire of making water is more frequent, the compressed bladder cannot contain a great quantity; the lower extremities become œdematous, and the veins of the legs varicose; women are also more subject to the piles: these effects depend on compression of the vessels that return blood and lymph from the inferior parts; and the cramps which pregnant women experience arise from the effect of pressure on the sacral nerves. The groins are painful, and twitchings are felt that may be attributed to the distention of the round ligaments of the uterus: at last the skin of the anterior parietes of the abdomen, by being so much distended, cracks when that of the other parts has yielded as much as possible.

Before it is explained how the uterus liberates itself from the fœtus and its membranes at the termination of pregnancy, some attention shall be given to the produce of conception, its progress, and the nature of its connexion with the mother.

History of the Fœtus and its Coverings.

CLIII. If the internal surface of the uterus be examined immediately after conception, nothing will be seen that discovers the existence of impregnation; but some days afterwards a transparent membranous vesicle is found, filled by a liquid jelly, in which no traces of organization and life can be detected. This small ovum, however, begins to grow, certain parts of the gelatinous liquid become of a firmer consistency, at the same time their transparency is diminished: it is then we can perceive the first lineaments of parts, the shape of the head, trunk, and extremities. The small ovum, which is at first unconnected in the cavity of the uterus (De Draaf), forms adhesions with this viscus; the whole of its external surface becomes like velvet or cotton; and this species of vegetation is in no place more strongly marked than where the placenta is found. About the seventeenth day, an hitherto homogeneous and semi-transparent mass manifests a more decided structure; a red point is seen in the place corresponding to the heart: it proves to be this organ itself, distinguishable by the pulsations of its cavities, and motions of the particles of red liquid that is contained in them. We should not infer that because the heart is the *punctum saliens*, it is the first to possess life *(primum vivens)*; and being the first perfected, that it exists before all other organs. All our parts are coexistent, and, according to the sentiment of Charles Bonnet, they discover themselves to the eye of the observer sooner or later, as by the nature of their organization they may be more or less able to reflect light. If a successive order in the formation of our organs were admitted, the brain and nervous system should exist before the heart, without even being perceptible on account of their transparency.

The red lines passing from the heart point out the course of the larger vessels which seem agitated: their coats are semi-transparent. In proportion as the blood, or rather its red particles, extends from the centre to the circumference, the form of the embryo becomes more evident, its parts grow with rapidity; certain points are discovered perfectly opake, and we can now judge of the shape of the fœtus: it is curved upon itself, and nearly resembles a French bean, suspended by the umbilical chord, which is formed with the fœtus and its coverings, as will be presently explained, and grows with them: it swims in the liquor of the amnion, and changes its posture with so much greater ease, as the space in which it is inclosed is larger in comparison with the smallness of its contents. In the progress of its growth it becomes extended, and is still curved (CXXIII.): the head constitutes its greater part; the superior extremities, like small shoots, bud first, then the inferior members: the feet and the hands seem immediately attached to the trunk; the fingers and toes have the appearance of small papillæ. The eyes are the first organs of sense that become apparent; they may be distinguished as small black points towards the end of the first month from the vitality of the embryo; the eyelids grow and cover them, &c. The mouth, at first open, is closed by the gradual approximation of the lips about the end of the third month; during the fourth an adeps inclining to redness begins to be deposited in the cells of the mucous texture, and the muscles to exert some motions. The growth is more rapid as the fœtus approaches the time of birth; it is impossible to estimate the weight and length of the fœtus according to the different periods of pregnancy, since the precise time of conception is never very certain; and as the increase is not equal in various individuals, one fœtus of six months may be as large as another at nine: however, at the time of parturition the body is generally 18 inches long (4 décimetres, 8 centimètres, 7 millimètres), and weighs from 7 to 8 pounds (3 kilogrames, 424 grames, 0,22 milligrames).

The secretion of bile, like that of adeps, seems to begin about the middle of pregnancy, and tinges the meconium yellow, which was before a mucus without colour, filling the digestive canal; the hair grows soon after; the nails are formed betwen the sixth and seventh month; a very fine membrane that hitherto closed the pupil of the eye is lacerated by means we are unacquainted with, and this aperture appears. The kidneys, at first numerous, that is, consisting of from fifteen to eighteen distinct glands, unite and from only one viscus on each side. The testicles, in the early part of pregnancy situated on the sides of the lumbar vertebræ and aorta, near the origin of the spermatic arteries and veins, afterward descend in the course of the iliac vessels to the groin with a cellular chord, called by Hunter *gubernaculum testis*, and pass through the abdominal ring, carrying down with them a portion of the peritoneum to form the tunica vaginalis.

This membrane of the testicles given by the peritoneum, not only covers these organs, and is reflected over them, but in adults also ascends about half an inch on the inferior part of the spermatic chord: the cause of its not passing so far as the ring is because all that portion that is continued from the ring to the testicle after birth is reduced to cellular texture. Upon considering the cause of the spontaneous decomposition of a portion of this peritoneal elongation, I found that nothing was more distant from being proved and less probable: in fact, in early life the testicles having passed from the abdomen by the abdominal ring, are not far removed from this aperture. That portion of the tunica vaginalis reflected over the spermatic chord is continued as far as the ring, and even beyond it, to unite with the peritoneum, as may be sometimes seen in congenital herniæ. It is only as we advance in age that the testicles descend farther into the scrotum; so that in adults the elongation that at first covered the whole of the chord, which, directly after birth, was only a few lines in length, when elongated to the extent of several inches, is found to cover merely its inferior part, without any decomposition being effected: a phenomenon as difficult to conceive as to explain.

CLIV. The principal difference that exists between the fœtus and the new-born infant, independent of the inactivity of the senses, and the repose of muscles subject to the empire of volition, is the manner in which the circulation of the blood is effected. The fœtus receives from the mother its aliments ready prepared, being yet too weak to assimilate extraneous bodies into its own substance. The arteries of the uterus convey a great quantity of blood to this viscus (CLII.): the whole of this fluid is not employed for its nourishment, but passes in considerable quantity from the mother to the infant by being poured from the uterine vessels into the cells of a spongy texture that adheres on one side to the uterus, and on the other to the ovum containing the fœtus.

This cellulo-vascular body, known by the name of placenta, is, with the fœtus and its coverings, the produce of the act of generation; although it generally adheres to the fundus of the uterus, it may be connected with any other part of its parietes: it is sometimes placed over its orifice, a circumstance that always renders parturition difficult. The side by which it is united to the internal surface of the uterus is unequal, rough, and covered with mammillary eminences, depressed in corresponding cells of the parietes of the uterus, the internal part of which loses its former smoothness, and has depressions *(sinus uterini)* destined to receive the lobes of the placenta, and also is covered with projections that correspond to the cells of the latter substance *(sinus placentæ)*.

The arteries of the uterus, and perhaps even the chylous vessels, so large and numerous in the impregnated uterus, that Cruikshank, who succeeded in injecting them, compares them to writing-quills, pour forth the arterial blood of the mother on the surface of the placenta and into its spongy structure: some physiologists are of opinion that it is only the serous part of this liquid; others say a chylous, lymphatic, white, or lactiform fluid. These humours, when extravasated into the cells of the placenta, are absorbed by the numerous radicles of the umbilical vein, which by uniting form the trunk of this vessel.

A German physician (Schreger) has just advanced an ingenious opinion on the mode of circulation that takes place from the mother to the infant. According to his doctrine, the uterine arteries only pour serum into the cells of the placenta: this serosity is absorbed by lymphatic vessels, which he presumes by analogy to exist in this organ and in the umbilical chord, where they have not hitherto been injected. These vessels carry it to the thoracic duct, which empties it into the left subclavian vein; it then proceeds to the heart, and thence to the aorta:

it returns to the placenta by means of the umbilical arteries, and becomes blood by the action of the organs of the fœtus. This serosity, changed to blood, returns into the body by the umbilical vein, and, following the course known and described, serves for the nourishment of its organs. The branches of the umbilical arteries and veins, ramified in the placenta, and communicating together in this spongy structure, give off by lateral pores that which is no longer required for the nourishment of the fœtus. This residuum of nutrition deposited in the cells of the placenta, is absorbed by the lymphatics of the uterus, which convey it into the circulating mass of humours in the mother.

The umbilical vein arising from absorbent branches in the internal part of the placenta, is detached from this body, and proceeding towards the navel of the fœtus, there enters into its abdomen, and ascends, supported by a duplicature of peritoneum, behind the recti muscles as far as the liver, through a fissure of which it passes, giving off a great number of branches to the lobes of this viscus. When it has proceeded as far as the right extremity of the transverse ridge, it partly unites with the sinus of the vena porta hepatica; while the remaining part, under the name of venous canal, follows its original course, and empties itself into the vena cava inferior, near its termination in the right auricle of the heart.

CLV. The arterial blood that flows into the umbilical vein greatly resembles venous blood, abounds in hydrogen and carbon, and has in some measure lost its vivifying properties, by having passed through the vessels of the mother, and the tortuous route of the placenta. It is in a great degree deprived of these latter principles, and revivified by passing through the liver, which at this period of life discharges those functions which the lungs after birth are destined to perform.

The liver, therefore, with the brain, forms the greater part of the weight of a new-born infant. This viscus alone fills the larger portion of the cavity of the abdomen; it acquires its bulk by attracting the hydrogen and carbon of the umbilical blood: its substance is fatty, oleaginous, and contains both these principles in considerable proportion. The secretion of the bile and fat, the only secretions that evidently take place in the fœtus, make up for the defect of respiration.

This blood poured by the umbilical vein into the vena cava inferior, and thus carried into the right auricle, does not there mix with the blood brought by the vena cava superior; for the orifices of these vessels, as before observed (XLVII.), not being directly opposite each other, the columns of blood do not meet in direct opposition. That portion contained in the vena cava passes through the foramen of Botallus, towards which it is inclined; it is thus conveyed into the left auricle, thence to the left ventricle, without having traversed the lungs, which being at this period compact and hard, could not have given a free passage to the blood: the contractions of the left ventricle propel it into the aorta, and its momentum is diminished by the large curvature of this artery; it enters the vessels arising from that part, and is carried to the brain and superior parts. This blood is the purest, the most highly oxygenated, and coming in direct course from the placenta; it has not yet circulated in the body of the fœtus, if we except a small portion of it brought by the vena cava from the pelvis and inferior parts; for the blood returned from the abdominal viscera receives a change in passing through the liver. The other parts of the body, on the contrary, receive a blood containing very little oxygen, since the remaining portion of fluid, which the contractions of the left ventricle and aorta have not propelled into branches arising from its arch, is soon mixed with the venous blood from the *canalis arteriosus* that enters just below this curvature: growth, therefore, being always relative, not only to the quantity, but also to the more or less vivifying qualities of arterial blood, is much more rapid in the superior parts before birth; so that the head alone constitutes the greater part of the body, and the shoulders, chest, and superior extremities are more developed than the abdomen, the pelvis, and inferior extremities.

The blood conveyed by the descending vena cava from the superior parts of the fœtus passes into the right ventricle; this impels it into the pulmonary artery, which only sends off two small branches to the lungs, and taking the name of arterial canal (*canalis arteriosus*), opens into the aorta immediately below the origin of the left subclavian artery. The beginning of the aorta is filled, consequently, by arterial blood driven towards the superior parts by the contraction of the left ventricle, and the other parts of this artery contain a venous blood propelled thither by the united power of both ventricles.

In this admirable disposition we cannot but observe an evident arrangement to fulfil a useful purpose. If all the powers of the heart, indeed, were collected to throw the blood towards the brain, the delicate texture of this viscus would have been injured; there required, on the contrary, the combined action of both ventricles to make the fluid pass through the long and tortuous routes of the umbilical chord and placenta (Harvey). The aorta, when descended opposite the fourth or fifth lumbar vertebra, divides, and by this bifurcation forms the two umbilical arteries. These give off only small branches to the pelvis and inferior parts, which carry a blood containing very little oxygen; the umbilical arteries then form a curvature round the sides of the bladder, incline inwards near the *urachus*, pass out of the abdomen by the navel, and, by a junction with the umbilical vein that had passed into the abdomen of the fœtus through the same opening, constitute the chord of *umbilical vessels*.

CLVI. The length of the umbilical chord from the navel to the placenta, is from 20 to 24 inches (6 decimètres, 4 centimètres, and 9 millimètres). It may be only six inches long, or even exceed the usual length, as proved by an observation of Baudelocque, who once found it 57 inches, and with seven turns round the neck of the child: this latter circumstance proves that the fœtus moves in the uterus. Of the three vessels that form the chord, the two smaller have an arterial structure, though conveying a fluid truly venous, while the umbilical vein carries arterial blood to the fœtus. The umbilical arteries, when arrived at the placenta, divide, and are lost in its substance by a great number of branches, the ultimate determinations of which deposit in the areolæ of its structure the blood that comes from the fœtus, and is to be returned to the mother. Does the passage of an injection of the umbilical vein, by being carried into the arteries, prove the existence of anastomoses between the extremities of these vessels?

It is by means of the umbilical chord and the placenta that the fœtus is connected to the mother. The veins or lymphatic vessels of the uterus, and perhaps both, receive from the spongy structure of the placenta the blood that has served for the nourishment of the fœtus, and return it to the mother, in order for it to be modified by the action of her organs, and chiefly by the effect of atmospheric air in its circulation through the lungs, to become again proper for the support of the fœtus. Whether we inject the vessels of the uterus, or push the injection by the umbilical vein or arteries, it never fills more than one part of the placenta, which has induced anatomists to consider this vascular mass as formed of two very distinct portions; one belonging to the mother, which has been called uterine, the other fœtal, from its constituting a part of the umbilical chord.

The vessels of the mother, therefore, only anastomose with those of the mother in the substance of the placenta; the circulation is not continued in a direct course from one to the other. If the communication were immediate, the contractions of the infant's pulse would be synchronous with those of the mother; but they are much more frequent, as may be discovered directly after birth, before the division of the umbilical chord. If we open the veins of a bitch ready to pup, the animal dies from hemorrhage; yet the placenta is only empty in that portion adhering to the uterus: the other part of this mass, as well as the fœtus, is distended with blood as in its usual state. It may be conceived that if the vessels of the uterus were continued without an intermedium of those of the placenta, parturition could not take place without rupturing them: the result would have been dangerous hemorrhagies, inflammation, and even suppuration of the organ that suffered; besides, the force with which the heart and arteries of the mother propel the blood in its vessels, would have affected the organs of the fœtus, too tender to bear such a violent shock. Although the placenta and umbilical chord are the means of connexion between the infant and its mother, yet it must be confessed that they more properly belong to the former.

CLVII. The existence of the fœtus is purely vegetative; it is continually receiving the fluids brought by the vessels of the mother to the placenta for its growth and nourishment. It may be considered as a new organ, the produce of conception, participating in the general life, but possessing a vitality peculiar to itself, and, to a certain degree, independent of that of the mother. From being curved upon itself, so as to occupy the smallest space, and to be accommodated to the oval figure of the uterus (CXXIII.), it cannot be considered as a man asleep; for not only are the organs of sense and voluntary motion in a state of perfect repose, but also several of the assimilating functions are totally unemployed, as digestion, respiration, and the generality of secretions: the fœtus, however, surrounded by the liquor of the amnion, performs spontaneous motions, which accoucheurs enumerate among the signs of pregnancy. Some have endeavoured to deny the existence of these phenomena, and to attribute the change of posture in the fœtus to a mere concussion; and this doctrine was supported on the intimate connexions that exist between respiration and muscular action. It has been affirmed, that since the blood of the fœtus was not impregnated with oxygen in its passage through the lungs, it could not keep up irritability; but, independent of a fact not being less certain on account of the difficulty of explanation, it may be answered that the mother performs this office with respect to the fœtus, and sends to it arterial blood proper to determine the contraction of muscles.

As we do not perform any motion but in consequence of impressions previously received, and as the sensitive organs of the fœtus are in a state of perfect inactivity, it seems difficult to say why it should act in the uterus of the mother. But touching takes place when any part of the surface of its body strikes the internal surface of the sac that contains it: in fact, internal impressions perceived by the great sympathetic nerves may be an occasional cause of it.

The fœtus is nourished, like every other organ, by appropriating to itself whatever is found in the blood brought by the vessels of the uterus proper for its purpose. The interception of this fluid by the ligature or compression of the umbilical chord occasions death, not, as some have considered, suddenly, and by an immediate suffocation: but the action of the organs should become gradually weaker, and ultimately cease when the fluids of the fœtus, being no longer vivified by the admixture of fresh juices supplied by the mother, would be completely deprived of their nutritive parts. It is now clearly demonstrated that the liquor of the amnion does not serve for the nourishment of the fœtus, whose mouth is closed, the head inclined over the chest, and the intestinal canal filled with a fluid different from that in which the body is immersed. Besides, does not the adipose substance, smeared over the surface of the skin, prevent the absorption that might otherwise take place from the external part of the body?

It was long believed that the fœtus existed in an erect posture during the first months of vitality, but that towards the termination of pregnancy it changed its position by turning with the head downwards: this error, credited by its antiquity, and by the coincidence of several physiologists, is completely refuted in professor Baudelocque's Treatise on the Science of Midwifery. To discover the absurdity of this hypothesis, it is only necessary to consider that the head of the embryo, being always the heaviest and the most voluminous part, must necessarily occupy the lowest portion of the uterus.

The size and strength of the fœtus are not relative to the powers of the mother. Fat and powerful women are occasionally delivered of weakly children, while slender and debilitated women bear children that are fat and healthy: yet these are only exceptions to the rule which generally obtains, that, *cæteris paribus*, the good state of the fœtus depends on that of the mother. The changes of fluids in the latter have an evident influence over the health of the fœtus: perhaps even this is the medium by which hereditary diseases are transmitted, which by others are attributed to certain alterations of the semen.

The fœtus is subject to different species of affections, whether arising in itself, or being received in the germ. Cicatrices are now and then found, that evidently prove solutions of continuity of various kinds. An infant born without any member may have been deprived of it in consequence of an affection experienced in the uterus of the mother. Professor Chaussier was sent for in a case of this description, and found a portion of the fore-arm among the *secundines*.

Since it is useful to study nature, even in her deviations from general principles, we shall say a few words on monsters, by reducing them into three classes according to Buffon, who calls those of the first, monsters by excess; those of the second, monsters by defect; and ranges those in the third class which possess a material alteration or false position of organs. In the first are enumerated such as have additional fingers, or even two bodies variously united; in the second are childen born with the hare-lip, or a deficiency of any part; and in the third, not only those individuals that present a general transposition of organs, as the heart, the spleen, and the sigmoid flexure of the colon on the right side, with the liver and cæcum on the left, but likewise those born with every species of hernia. We may add to these monstrosities such spots of the skin as are always in colour like some of our humours, but of various forms, that have no relative proportion, although, from an ancient prejudice, men have endeavoured to find resemblances more or less striking to those things which pregnant women have longed for during the time they were subject to those strange and extraordinary appetites that so frequently accompany uterogestation.

Among those who have wished to discover the causes of these malformations, some, as Mallebranche, attribute them to the power of the mother's imagination over the fœtus; others, as Maupertuis, have been of opinion that the passions by which she is agitated, inducing disordered motions in the humours, and the latter being violently carried to so tender and delicate a body as the embryo or fœtus, might be capable of deranging its structure. It is much more probable that the complaints which affect the mother during pregnancy may be the cause of them.

If two embryos, contained in the same ovum, be placed back to back, and the surfaces of contact should become inflamed, their mode of union may be easily perceived. If we put the fecundated ova of a tench or any other fish into a small vessel, the numerous young not having sufficient space to grow, become joined to each other, and hence will arise monstrosities in fish.

We must not give too implicit confidence to every thing extraordinary that has been advanced on this subject by writers of antiquity, and even those of later times. In reading the periodical collections published during the seventeenth and beginning of the eighteenth century, as the Ephemerides of the Curiosities of Nature, *Journal des Sçavans*, &c. we are surprised at the number of extraordinary circumstances related. In one there is mention made of a child born with a pig's head; in another a woman is delivered of an animal exactly like a pike-fish. There was a time, says a philosopher, when all philosophy consisted in seeing nothing but prodigies in nature.

The Covering of the Fœtus.

CLVIII. The name *secundines*, or after-birth, is given to the coverings of the fœtus, because they are not expelled till after it has left the uterus, and parturition is not completed until this is also brought away, called by accoucheurs delivery. The oval sac that contains the fœtus is formed of two membranes applied to each other: the one is named chorion, that adheres by its external and velvet-like surface to the internal part of the uterus; the other, thinner than the former, and concentric with it, may be considered the secretory organ of the liquor, which in conjunction with the fœtus distends the ovum, and is known by the name of amnion. The third membrane admitted by Hunter, and called by him *decidua*, is only the woolly texture presented by the external part of the chorion, when a number of cellular and vascular filaments are ruptured, by means of which the ovum was attached to the uterus. The placenta itself is only a thicker portion of this spongy texture, in which the umbilical vessels ramify: the uterus is also thicker in this part, because the communication of the fœtus with the mother is here more active.

The liquor secreted by the amnion is a serous fluid of agreeable smell and insipid taste, somewhat turbid, with a milky substance which it holds suspended, and is a little heavier than distilled water, 1,004. It is almost totally aqueous, since the albumen, soda, muriat of soda, and phosphat of lime, found by Buniva and Vauquelin, only amount to 0,012 of the whole mass. It turns the tincture of violets green, and reddens that of turnsole: this is really singular, because it indicates the coexistence of an acid and an alkali in a distinct state. The latter is in so small a quantity, and so volatile in the liquor of the amnion of women, that it never has been obtained separately, although a particular acid is found in the liquor amnii of cows, and called by Buniva and Vauquelin *amnotic acid*. The quantity of fluid contained in the amnion bears a greater proportion to the size of the fœtus in the early state of pregnancy: it is produced by arterial exhalation. Its constituent parts are brought by the uterine vessels of the mother. This is proved not only by analogy, but likewise by the observation of the relation that exists between the qualities of the liquor of the amnion and the mother's regimen; for which reason it will whiten copper when mercurial frictions have been employed during pregnancy.

The top of the bladder in the fœtus of quadrupeds is continued with a canal which is found imperfectly formed in man, and called *urachus*. This canal is joined to the vessels of the chord, passes with it out at the navel, and terminates in a membranous sac between the chorion and amnion: this is the *allantois*, always existing in the animal fœtus, but little perceptible, and often wanting in that of man. Several anatomists, however, say that they have seen the urachus, generally ligamentous, arising from the human bladder and ending in a small vesicle, that some have compared to a melon-seed, while others maintain that it is not larger than hemp or millet seed. So small a vesicle, when it does exist, certainly cannot serve any particular purpose, as the urachus mostly forms a solid chord, seldom possessing even a small perforation in that portion nearest to the bladder. The existence of these parts furnishes a new proof of what has been said when speaking of the uses attributed to the valve of the cæcum; that there exist in the bodies of animals organs that are of no utility, and merely exist as an evidence of the plan to which nature is subject in the production of beings; and of the gradations constantly observed in establishing the distinction of species.

On the natural term of Pregnancy.

CLIX. The fœtus can dispense with the influence of the mother when it has existed seven or eight months, reckoning from the instant of conception. All accoucheurs agree that it may live at this period; and that if it should remain two months longer in the uterus, it is in order to acquire more strength; and to be better able to resist new impressions to be afterwards experienced when born. When the ovum is detached before this period of maturity, the infant is still-born, or expires in parturition: premature births have been found to live at six months; but in general the life of the infant is more certain in proportion to the full term of utero-gestation, which is about the end of the ninth solar, or tenth lunar month. It is observed that children of seven months, however robust they may afterwards become, are born weakly, their eyes shut, and that they pass the remaining two months, during which they should have continued in the uterus, in a state of extreme debility and suffering: this sufficiently proves the necessity of a pregnancy protracted to the end of the ninth solar month.

If the fœtus can be detached from its mother, and live before the ordinary time, may it not likewise remain longer than usual in the uterus, have a more tardy growth, and not be expelled before some days, weeks, or even some months after the accustomed period? and how difficult is it therefore to assign the precise term beyond which it should be improper to believe in the possibility of a protracted parturition?

Examples are brought forward of children born more than ten months after the act of fecundation; and yet the laws, which cannot be established on rare exceptions, do not prolong the term of legitimacy in infants born so long after the civil dissolution of marriage.

On Delivery.

CLX. When the fœtus has remained in the mother's womb long enough to acquire a degree of power necessary for its existence alone, it is expelled, and carries down those parts that served for its covering and attachment to the uterus. The name of *delivery* has been given to the expulsion of this viscus. Nothing is more ridiculous than the opinions that have been formed by several authors, of the determinate causes of this phenomenon. According to some, Fabricius of Aquapendente, for example, it is the necessity of refreshing itself by respiration that causes the fœtus to rupture its membranes: others have maintained that it is impelled to this action by the necessity of evacuating the meconium, an excrementitious liquor that fills the intestinal canal; or that the fœtus is urged on to this action by the want of nourishment; or that parturition depends on the reaction of the fibres of the body of the uterus, which being extremely distended towards the end of pregnancy, return on themselves, and overcome the resistance of its neck that has been gradually dilated and diminished in thickness. But in this latter hypothesis, the only one in repute at present, why does not a woman whose uterus has a determinate capacity, fall into labour in the middle of the regular term, when a double conception, that is, twins, which with their fluids and membranes fill the cavity of the uterus, cause it to experience at that time the same degree of extension as that which would have been produced by a single fœtus at the completion of the natural period?

Although conception is most commonly single in the human species, that is, each parturition produces only one individual, yet it is not uncommon to find a woman give birth to two infants at once. It has been calculated that twins are born in the proportion of one to eighty; besides, there are examples on record of three, and even four children being delivered from the same conception, without mentioning instances where a still greater number has existed, because those observations are destitute of authenticity.

It is well known, that, in twins, each fœtus has its umbilical chord, which sometimes terminates in a separate placenta, at other times in one only. The same chorion invests both; but each of them has a distinct amnion and fluid by which it is surrounded. It would be curious to observe, whether a woman delivered of twins has two *cicatriculæ*, like animals, either existing in the same ovarium, or one in each. Twins generally have great resemblance in manners and traits of character.

Two children born after an interval of some months cannot be called twins, although they have existed together in the uterus during a certain period. The possibility of these superfetations is proved. They have been attributed to the existence of divisions in the uterus, that sometimes separate its cavity into two portions, merely because this disposition explains to a certain degree how two conceptions may take place at some distance from each other; for it has never been proved, by inspection after death, that women, in whom superfetations had happened, were possessed of a double uterus.

It is a fact, that for a fortnight, or even a month previous to delivery, the uterus seems to prepare itself for the expulsion of the fœtus. This sentiment, at least, may be inferred from the projection sometimes perceived on examining the neck of the uterus, evidently produced by a portion of the ovum and its fluid in the os uteri.

There is a period of maturity in the product of conception, that is, a term in which it can exist separated from the mother. When this time has arrived, the ovum, in which it is inclosed, detaches itself from the uterus by a mechanism that has a close resemblance to the mode by which the petal of a fruit leaves the branch supporting it. The fœtus probably then refuses to admit the blood carried to it by the umbilical vein; the placenta becomes distended; a stagnation of fluids is gradually transmitted to the uterus and parts in its vincinity. These organs, stimulated by the presence of this surcharge of fluids, enter into action; the woman has pains, which are at first vague, irregular, and like gripings; afterwards they change their character and become more acute, accompanied with a sensation of constriction directed from above downwards, that is, from the fundus to the neck of the uterus. Then this contractile sac, assisted by the diaphragm and abdominal muscles, redoubles its expulsive exertions; the pains become still more acute and frequent, the face is red and animated, the pulse full and rapid: the whole body seems to participate in the anxiety of the womb, agitated by the efforts of expulsion. The ovum, with its fluid, is pressed like a wedge into the orifice of the uterus, the edges of which are greatly weakened: the efforts are now stronger, the membranes rupture, the liquor of the amnion escapes, the head of the infant becomes engaged in, and passes through the orifice, during which period the pains are most excruciating.

They are more particularly intolerable when the sacrum of the woman is not sufficiently concave: the nerves of the crural plexus are then violently compressed by the head of the fœtus. This part of the body is generally presented first; it passes through the superior part of the pelvis in an oblique direction, that is, the occiput turned forwards, and corresponding to one of the cotyloid cavities, while the face looks backwards, and is opposite the sacro-iliac symphyses. It thus presents itself to the larger diameter of this passage; but in descending into the small pelvis it makes a curve, by means of which it also passes through the inferior portion of the pelvis, in the direction of its greatest diameter. The head descends through the vagina, appears externally, and soon disengages itself, followed by the shoulders and remaining parts of the body. It is in this manner that nature, after having effected fecundation by an act of pleasure, expels its production amidst the sufferings of pain.

CLXI. The passages through which the fœtus passes out are too narrow in the ordinary state for its exit to be effected without lacerations, if nature, as will be presently seen, had not arranged every thing to facilitate delivery. In fact, if on one part she has formed the cranium of the fœtus of flexible portions, separated by intervals that are membranous and not ossified, which permit the bones in some degree to lap over each other, and the size of the whole head to be reduced in descending through the pelvis of the woman; so, on the other hand, has she connected the bones of this latter part in such a manner as that their articulations visibly relax towards the termination of pregnancy. During the existence of this state, the humours of the mother are directed from all parts to this cavity and the organs contained in it: the ligamento-cartilaginous symphyses of the pubis of the sacrum and the coccyx, distended by the afflux of fluids, unite less firmly the bones between which they are situated. After being thus softened and tumefied, they are not separated from each other as by a wedge, to augment all the diameters of the pelvis, but serve to render distention more easy, when the infant's head makes efforts of pressure against them in passing through its different portions. It is on the more or less marked relaxation of the symphyses of the pelvis at the period of parturition that the indication of the section of that of the pubis is founded, and performed with success by Sigault and professor Alphonsus Leroy. Analogical induction, as Thouret has judiciously observed, should naturally lead us to this operation on the same principle as practitioners were induced to invent and employ the forceps, by a consideration of the means adopted by nature to diminish the size of the head.

The foresight of nature is not confined to render easy the action of the bony parts of the cranium of the fœtus and of the mother's pelvis; her influence has been extended to the soft parts of the latter, moistened with mucus, which relaxes their texture some days before delivery, and renders them disposed so as to admit of very considerable distention by the unfolding of their rugæ and plicæ without laceration, as before observed (CXLIX.) As the expulsion of the placenta and membranes does not immediately follow the exit of the fœtus, it has been usual to divide the placenta near the navel. It is unnecessary to make a ligature on the chord next the mother; all communication between the placenta and uterus is intercepted, so that only the blood contained in the former can be effused. The same condition does not obtain with respect to the portion left with the fœtus, although the changes which happen in the circulation at the instant that the chest dilates, and permits the air to expand the pulmonary structure, carry the blood from the umbilical vessels; yet these changes in the motion of the humours might not take place at once, but gradually, on account of the debility of the infant; and it is always prudent to obviate an hæmorrhage that would increase this weakness, by making a ligature.

It is very uncommon and always dangerous for the human ovum to be detached entire, that is, for the fœtus to be expelled with its membranes and fluids, since the latter should not be evacuated until a quarter of an hour, half an hour, an hour, or a still longer period, has elapsed from the delivery of the fœtus. When the uterus is completely emptied, its cavity becomes obliterated by the approximation of its parietes: the organ, thus contracted on itself, is concentred behind the pubis, and a constriction of its neck sometimes opposes delivery when it has been a tedious labour. The parietes of the uterus, distended with fluids, still remain thicker than in their natural state; but they are gradually emptied by the flowing of the lochiæ, and return to their former state.

When parturition is accomplished, the uterus falls into a state of repose, and sleep, if the expression be admitted, after such a laborious exertion. The humours cease to be directed towards this organ, in which an irritation no longer exists, to be carried to the mammary glands, and to furnish means for the secretion of the liquor that is to serve for the nourishment of the new individual.

Suckling.

CLXII. Nothing is more generally known in physiology than the close sympathy between the uterus and breasts; an intimate connexion, by which both these organs are developed at the same period of life, and cease together to perform their functions when the female becomes incapable of contributing towards the reproduction of the species. We shall not endeavour to explain this sympathy by nervous influence, or by the anastomoses of the epigastric with the internal mammary arteries, a communication that does not always exist, for they frequently terminate in the substance of the recti muscles of the abdomen before an union takes place; and even when this should be the case, as strongly marked as may be observed in some subjects, it could not be adduced as a proof, since the uterus and the breasts do not receive blood at all, or at most have only small branches from the mammary and epigastric vessels. The breasts increase in size during pregnancy, but they are never more swelled than after parturition.

The new-born infant brought near these organs, applies its mouth to the nipple, drawing back the tongue, and at the same time closely embracing the nipple with the lips, it draws towards itself the milk, the flowing of which is facilitated by the straight direction of the lactiferous tubes. These canals, from twelve to fifteen in number, are not only more perfect when the nipple, which is principally formed of them, elongates in consequence of the drawing exerted by the infant; but are also excited by its touch, experience an erection, contract, and propel the liquid. This excretion, like that of other glands, is assisted by the touches and pressure exerted by the infant's hands on the breast of the nurse. These light compressions are not so useful to express the milk mechanically, as to raise the organ to a state convenient for its excretion.

The erection of the nipples by the tickling of the breasts, the spasmodic and convulsive action that succeeds this kind of excitement, may be carried to such a degree as to cause them to throw the liquid by jets to a certain distance. While this excretion continues, women experience a sensation in the breasts that is not destitute of pleasure. These parts are tense and swelled, they have a sensation as of the milk ascending; some feel a drawing that extends to the axilla, arms, and chest: the whole of the cellular mass that surrounds the breasts and circumambient parts participates in their activity.

The breasts themselves are in a great measure formed by cellular texture; an adipose and lymphatic mass covers the gland divided into several lobes, and envelops its substance: the breasts receive a considerable portion of nerves, but very few blood-vessels, if compared to their volume.

Their structure seems to be chiefly lymphatic. These vessels, after having ramified in the neighbouring glands, and principally in those that are situated in the axilla, pass to the breasts, where their proportion, in comparison with that of blood-vessels, is as eight to one. This vast number of lymphatic vessels that enter into the composition of the breasts, are greatly augmented in diameter in women who give suck; and by injecting them in this state, we may be assured that several of them are united to form larger trunks, which being directed towards the nipple, go to constitute what have been called lactiferous tubes. If the lymphatic vessels have an immediate continuation into the excretory ducts of the breast, we shall be obliged to conclude that the fluid for the secretion of the liquor they supply is brought by this order of vessels, particularly if it be considered how small a number of arteriolæ are distributed in their structure, and what a disproportion exists between the diameter of these small vessels and the quantity of milk furnished by the breasts.

CLXIII. The granulated structure is not so apparent in the breasts as in other glandular organs; they have, therefore, a greater resemblance to lymphatic than to conglomerate glands. The milk formed in them has been at all times considered very analogous to chyle, of which it possesses the whiteness, sweet smell, and saccharine taste; it is also like the chyle in being the least animalized, and the softest animal liquor, that which organic action has least altered, and which most preserves the active qualities of the food taken by the nurse.

Is it not well known that the medicine of sucking children most frequently consists in administering it to the nurses; that the milk thus acquires purgative qualities, and acts in this manner on the infant's intestines, when the woman who gives suck has been purged?

The milk, however, is not in every respect like the chyle, although it may be considered an extract from the aliment (*Lac utilis alimenti est superfluum*, Gal. *De Usu Part.* lib. vii. cap. 22.), changed in the route it has to make to arrive in the breast by glands that intercept its direct passage, and particularly by the peculiar action of this organ.

This action is so marked, that, as Bordeu observes, "There are women who seem to have no milk in the breasts, which are flaccid; but so soon as the infant excites them they swell up, and the milk comes." It is also known, and well explained by the same author, that woman, the cow, and the females of other animals, more willingly suffer themselves to be milked by one who knows how to raise their sensibility and to stimulate the nipple; while, on the other hand, they retain the milk when the sensation they seem to enjoy is not produced. It is believed, in certain countries, that serpents understand how to tickle the cow's teats, and that the animals consequently suffer themselves to be sucked by this reptile.

The properties and chemical Nature of Milk.

CLXIV. Its quantity is generally relative to that of the aliments, their quality of nutrition, and bears a proportion to their moist and farinaceous properties: although it may amount to a third part, or an half, of the quantity of food taken by the nurse, it may also exceed or be less than this proportion. Its weight, even in woman, whose milk is lightest, is more than that of distilled water, and is always relative to its consistency: the latter property is inconsiderable in the human species, but becomes greater as we pass from it to the cow, the goat, the mare, the ass, and the ewe. Its fluidity is in a medium between aqueous and oleaginous liquids; its colour, odour, and taste, have something peculiar to itself, and cause it to be easily distinguished: in fact, it is not exactly the same at different periods of the same milking. This has been proved by Deyeux and Parmentier in their work on Milk, a book replete with important observations, and which may be considered a complete history of this animal liquor. They have seen that the milk, first drawn from the cow's teat, was of a serous quality; that its consistency was gradually increased, and that the milk last drawn was thickest; as if the liquid contained in the ubera obeyed the laws of its gravity.

The milk, when exposed in a vessel to a free current of air, is decomposed, and separates into three parts: the *serum* or whey, the *cheesy part*, and the fatty or butyraceous part. The latter, being lighter than the other, is always found on the surface; and its relative proportion not only depends on the goodness of the milk, but also on the extent of surfaces by which it is in contact with the air; which proves, as Fourcroy had first observed, that the oxygen of the atmospheric air has some influence in its separation. The caseous part, spontaneously concrescible, seems to be an albumen abounding in oxygen. Deyeux and Parmentier consider it to be the cause of colour of the milk, and of its most characteristic qualities. Lastly, the serum, which alone constitutes the greater part of this liquid, contains not only a particular acid (the lactic acid) but likewise a saccharine body that can be extracted by evaporation, and when crystallized into rhomboidal parallelopipedes, forms the sugar of milk, which is more or less pure according to the care taken during the process of its preparation. When Scheele first endeavoured to change this sugar of milk into oxalic acid by means of nitric acid, he found that it contained a peculiar white acid, difficult of solution, to which he gave the name of saccholactic acid. The milk may be considered one of the most complex of the animal liquors, the qualities of which are very variable, and of which the parts have but a weak union, so that it decomposes itself with the greatest facility. This kind of emulsion contains so little azot, that it still preserves its vegetable character; hydrogen, carbon, and oxygen predominate: several salts are discovered to exist in it, and, among others, muriat of soda, muriat of potash, and phosphat of lime.

The presence of the two latter gives rise to the following considerations. Muriat of potash, as observed by Rouelle, does not exist in the blood; it is not therefore this liquid that carries to the breasts materials for the secretion of milk, in which this salt is more abundant than the muriat of soda. These salts of potash are found, on the contrary, in great proportion in the chyle extracted from vegetable aliment; a fresh proof that the milk is furnished by the system of lymphatic vessels. The calcareous phosphat which is found to exist in very small quantity in the urine of nurses, and is carried towards the breasts, was a property indispensable to the liquor that nourishes the new individual during the time in which all the bones are becoming harder, and every part is increasing in solidity.

If, however, we wish to ascend to the causes that render suckling necessary, and subject the infant to this particular mode of nutrition, we shall find it dependent on the general weakness of its organs. Those of digestion would not have extracted from the food their nutritive parts, as these substances could not have suffered the degree of trituration necessary, from a deficiency of teeth and a debility of the masticatory organs. It was requisite, therefore, for the mother to be invested with this first work, and to supply it with the aliment already digested (*Lac est cibus exactè confectus.* Galen. *De Usu Partium*, lib. vii. cap. 22.); yet we are not to believe that the milk passes into the vessels of the infant without alteration; it digests this aliment in a manner peculiar to itself, and receives from it in a short time, and without exertion, a great portion of its nutritive parts, necessary for the rapidity of its growth.

The bonds of union between the infant and mother are, therefore, far from being dissolved at the moment of birth; their mutual connexions, though less intimate, are not indispensable. Before the infant was born, its vital power was so confined, that it was obliged to receive a liquor already animalized, already disposed to assist the action of the nutritive and assimilating powers. After birth, its powers having been increased, it may be invested with a greater share in those functions; it is only necessary for the aliment to have passed through its first elaboration effected by digestion; but it is not only for the preparation of its nourishment that the new-born individual requires the assistance of the mother; its lungs, delicate and imperfectly developed, do not sufficiently oxydate the blood passing through them; animal heat would be too low for the necessities of existence if the mother were not to obviate this deficiency by transmitting to it a portion of her own warmth. She gently presses it to her bosom, warms it with her breath, and by this kind of maternal incubation continues the influence of caloric, to which it was extremely subject during the time it constituted a part of herself. Besides, the mother perceives for it, anticipates its wants, attends to its calls (*language*): this moral and affecting communication established between them, counterbalances the relaxed but undissolved bonds of physical communication. The infant, therefore, is detached by gradations from her of whom it held existence, since it is only as it advances in age that means of living independent of the mother are acquired.

The air does not dilate every part of the lungs in the first inspirations of the infant after birth: frequently some portion of the lobes is more firm and compact, does not immediately admit this fluid, being sometimes even impervious to its passage. An infant died on the twentieth day: Professor Boyer was called to open it. Upon an examination of the lungs, he found that their posterior part had preserved the same hardness as exists in a fœtus: the anterior part only was swelled, distended with air, crepitating, lighter, and swam when thrown into water. It was considered necessary to investigate whether the structure of the heart could account for this difference, which might have also depended on the ability of the powers of respiration. The foramen of Botallus was found open, so that the blood could pass from the right to the left cavities of the heart, without being obliged to pass through the pulmonary structure. The infant had remained in a state of continual languor during the whole period of its short existence: its skin was sometimes pale, at other times of a violet hue. It was kept warm with difficulty.

Madame L——'s infant died on the ninth day after delivery: it had manifested the same phenomena. I opened the chest, and found the surface of both lungs hard and compact: the foramen of Botallus was completely preserved. This aperture is often found partially closed, so that there always remains, under these circumstances, a perforation on the superior part of the oval foramen of greater or less extent, by which a small quantity of venous blood might pass from the right into the left auricle, if both these cavities did not contract at the same instant, and if the liquor that distends them were not opposed to an equal resistance on all sides. We are in possession of some observations of individuals in whom the foramen ovale remained, and who, nevertheless, lived to a tolerably advanced age. Their skin was blueish and livid, their bodies cold, all their physical and moral faculties weak and benumbed. It would be interesting to prove by ocular demonstration, *post mortem*, whether the most expert divers, who can remain the longest time under water without coming to the surface for respiration, have not this aperture imperfectly shut.

Sometimes the infant comes into the world and offers no sign of life. When the circumstances of the labour do not justify a suspicion that it has suffered any organic injury that is decidedly mortal, it should be considered as asphyxia from weakness, and every assistance that is recommended in similar cases must be employed; particularly propelling air into the lungs by means of a straw or tube, passed into the mouth or nostrils. It was in this manner that the prophet Elisha recovered the son of the Shunamite, as mentioned in the 4th chapter of the 2d book of Kings.

The afflux of milk towards the breast can be prevented by the irritation of the uterus. If parturition have been laborious and difficult, and the woman suffered by injury of parts, the irritation those parts experience prevents the humours from being carried towards the breasts. These organs are therefore found to collapse when puerperal fever is present; not that the milk returns into the mass of humours, and becomes the cause of a disease, but because the inflammation of the uterus prevents the fluids from following their natural direction.

During the first days that succeed delivery, the parietes of the uterus empty themselves by an effusion at first bloody, then reddish, and ultimately mucous and whitish, to which authors have given the name of *lochiæ*.

CHAPTER XI.

THE HISTORY OF THE AGES, TEMPERAMENTS, VARIETIES OF THE HUMAN SPECIES, DEATH, AND PUTREFACTION.

Infancy.

CLXVI. THE epidermis of the new-born infant becomes thicker, the redness of its skin less marked, and the wrinkles obliterated; the down covering its face falls off, its thighs augment, and soon conceal the aperture of the rectum. During the first months of life it seems to have no other wants but those of nourishment and sleep; yet its understanding begins to be formed, it looks at objects with a fixed eye, and endeavours to acquire a knowledge of all surrounding bodies. Its existence, confined at first to unpleasant sensations, expressed by almost continual crying, is rendered less painful as it becomes accustomed to the impressions exerted by external objects on its weak and delicate organs. Towards the middle of the second month it can experience agreeable sentiments: if any be perceived before that time, they are not at least expressed by smiling. (*At Hercules risus præcox ille et celerrimus ante quadrigesimum diem nulli datur*. Plin. Hist. Nat. Præf. ad lib. viii.)

Dentition.

CLXVII. Towards the end of the seventh month, the middle incisor teeth of the superior maxilla perforate the texture of the gums: soon afterwards the corresponding incisors of the lower maxilla appear, then the lateral incisors of the superior maxilla, those of the inferior, the canine teeth, which appear by following the same order as the incisors, that is, the superior always precede the inferior. The small molares appear between eighteen months and two years after birth, but in an inverse order: those of the inferior are produced before those of the superior maxilla. When these molares are above the gums, the first dentition is completed; the child's life is now more secure; it had been hitherto very uncertain, since calculations on the probability of the duration of human existence prove, that a third of the number of infants born at any given period die before they attain the age of twenty-three months. Convulsions and serous diarrhœas are the most dangerous accidents that accompany difficult dentition. Towards the end of the fourth year two other molares in each maxilla are added to the former twenty teeth: these will afterwards constitute the first large molares. They differ from the preceding, as they are to remain during life; but the primary or milk-teeth fall out near the seventh year, agreeably to the order in which they came, and are replaced by other teeth, that are larger and better formed, their roots longer and more extended, except the small molares. Towards the ninth year the child has two additional large molares situated beyond the former. There are then twenty-eight teeth, and dentition is complete, although from the age of eighteen to thirty years, and sometimes much later, two teeth in each maxilla, called *dentes sapientiæ*, appear at the extremity of the alveolar processes.

It would be a difficult task to explain why a tertian fever frequently terminates spontaneously at the seventh accession, while a continual fever is influenced by critical evacuations at seven, fourteen, or twenty-one days: why parturition should take place at the expiration of nine months; the first dentition begin at seven months, the second at seven years; why puberty should manifest itself about the fourteenth year, and menstruation be repeated at determinate periods. Nature seems to have rendered herself, in all her acts, subject to certain periods which observation can determine, without the possibility of ascending to the cause of these phenomena so easy to be proved. From their appearance being correlative with certain numerical terms, we are not to give credit, like Pythagoras, to the power of numbers, and to believe the numbers 3, 7, and 9 render all nature subject to their supreme influence; of which sentiment he was the fabricator. Vestiges of this ancient error are to be found in all sciences, in every religion, even in those that are professed and respected in the most enlightened nations.

This double row of teeth that succeed to each other existed in the maxillæ of the fœtus. Each alveola at this period of life contains two membranous follicles. That which is to form the primary tooth swells first; a calcareous matter incrusts on its surface, and forms the body of the tooth, which thus obscures the follicle that secretes the bony part; so that when the formation of the small bone is completed, the membranous vesicle, in the parietes of which the dental vessels and nerves ramify, is in the centre of its body, and adheres to the sides of its internal cavity. It is difficult to allege a reason why the evolution of the dental germs is successive; why, in the seventh year, the primary teeth are detached, and replaced by others, that have so long remained buried in the substance of the alveolar processes. Dentition, like every other phenomenon of the animal economy, presents us with an innumerable assemblage of varieties, with respect to its period, duration, &c. Teeth therefore have been known to be produced a third time in persons far advanced in life, and there are some examples on record, though very uncommon, of children born with two incisors in the upper maxilla; supernumerary teeth are frequently found to exist, &c.

Ossification.

CLXVIII. The exertions of the bony system are not confined to the eruption and completion of the small bones that are situated in both maxillæ. All the other parts of the skeleton become harder; a deposition of bony matter is found in the centre of cartilages that correspond to the small bones of the carpus and tarsus; the thickness of the cartilaginous parts that separate the epiphyses from the body of the long bones diminishes; the broad bones grow and become solid from the centre to the circumference. Those of the cranium come into contact at their margins; their fibres intersect, and form sutures; and the cartilaginous spaces *(fontanels)* that existed between their margins and angles become obliterated. The urine contains very little phosphat of lime, as this salt is employed for the solidity of bones. Towards the middle of the second year these parts have acquired a sufficient degree of consistence and solidity to support the weight of the body, the child is able to stand erect and to walk. Before this time it would have been dangerous to make these efforts; the columns of support, from being too flexible, would have yielded under the burden, forming different curvatures; and the direction of the limbs must necessarily have been viciously altered. The vital motions of infancy tend towards the head; this part is therefore the principal seat of diseases peculiar to that age, and productive of affections in which local evacuations are frequently useful.

The organs of the senses, open to all kinds of impressions, receive them with facility; but if sensations in early infancy are easily impressed, they are not very durable, which is doubtless dependent on the want of firmness of the brain. As the child advances in age, its mobility is moderated without a diminution of susceptibility; and it is during those years which precede the tumultuous period of puberty that it enjoys the most elevated degree of power of recalling to mind past occurrences; its memory is at this time also most clear and comprehensive: but it soon becomes governed by the imagination, from which a powerful reaction of the sexual organs on the brain diverts its influence, and it ceases to have the same fidelity.

Puberty or Adolescence.

CLXIX. Sex, climate, and manner of living, have a great influence on the earlier or later appearance of the phenomena of puberty. Woman attains to this state a year or two sooner than man, and the inhabitants of southern, long before those of northern countries. For this reason, in the hottest climates of Africa, Asia, and America, girls are marriageable at ten and even at nine years of age, while in France they are not until the twelfth, fourteenth, or fifteenth year; and in Sweden, Russia, and Denmark, menstruation, the most characteristic sign of puberty, is two or three years later.

It is discovered that a male is capable of propagation, and that *the life of the species* begins to exist, by the emission of a prolific semen, and by the alteration of the voice, which becomes fuller, deeper, and more sonorous; the chin is covered with a beard, the genital parts are shaded with hair, and speedily acquire the magnitude they afterwards preserve: the whole body augments; the general characters that distinguished the sexes, which were so obscure before puberty, and could have been mistaken by a transitory view, are now so strongly marked, that it is impossible to be deceived in them.

In addition to the other signs of power and puberty, the sexes, irritated by desires, which may be termed wants, distinguish the means of being satisfied. The change of the voice is the most certain index of an acquired aptitude for the act of reproduction. The following observations prove that it arises from the increasing perfection of the vocal organs, which always accompanies that of the sexual parts.

CLXX. A young man died at fourteen years of age in the hospital La Charité. On opening the larynx I was surprised at its smallness, and particularly at the very inconsiderable extent of the glottis, which was only five lines in diameter from the anterior to the posterior part, and about one line and a half across at its broadest part. The most material point in this case is, that although the individual was tall, yet the perfection of his genital parts was as little advanced as that of the organ of voice. I have made the same observation in subjects more remote from the period of pregnancy; I have extended my researches to those who have passed it, and obtained for a general result, that the difference of size between the larynx of a child three years old, and of another of twelve, is not very remarkable, almost imperceptible, and bears no proportionate comparison with their general stature.

That at the time of puberty the organ of voice rapidly increases; and that, in less than a year, the aperture of the glottis augments in the proportion of 5 to 10; that its extent is, in fact, doubled both in length and breadth.

That these changes are less strongly marked in woman, whose glottis only enlarges in the proportion of 5 to 7; that in this point of view, she resembles children, as the tone of her voice already indicated.

These differences in the size of the glottis account for the danger attending *cynanche trachealis*, or croup, in children. Admitting that it may have an aperture of a line and a half in breadth, and the edges of which are covered with an albuminous lamina of three quarters of a line thick, the opening will be entirely closed; but it would be only rendered narrower, and a sufficient space might still exist if its breadth were twice as much. This supposition, adduced to render myself more intelligible, is, however, merely an exposition of the truth, since an anatomical inspection demonstrates that the glottis is twice as large in adults as in youth before puberty.

Menstruation.

CLXXI. The symptoms by which puberty is distinguished in females are not less remarkable. The swelling of the genital parts renders their apertures and canals narrower; the breasts become round and elevated, forming considerable projections beyond the thorax; besides, they become subject to a sanguineous discharge that takes place every month from the vessels of the uterus, and is known by the name of *menses*. This periodical evacuation manifests itself in most women by all the signs that indicate a plethora of the circulatory system; as spontaneous lassitude, flushes of heat in the face, animated and lively countenance, and by others, that manifest a direction of the humours towards the uterus, local plethora of that organ, as pains in the lumbar regions, a particular itching in the genital parts. The first appearance of the menses terminates this state, which in numerous instances may be considered a real disease: a pure and crimson blood flows in greater or less abundance for several days, and the female is relieved from those oppressive symptoms.

We shall not here treat of the numerous deviations that the menses may suffer, and which should be regarded as so many diseases. The discharge from the uterus has been found to be occasionally supplied by nasal hæmorrhage, hæmoptysis, melæna; sometimes by unusual sanguineous discharges from the eyes, ears, indicator-finger, and from ulcerated surfaces in different parts of the body. This evacuation, at first irregular, afterwards becomes periodical every month, lasting from two to eight days, and evacuating from three ounces to a pound of blood at each time. In women of a sanguineous temperament, robust, and libidinous, the menses remain longest, and flow in the greatest quantity. The blood effused is red, arterial, and, in a healthy subject, does not possess any of those ill qualities that have been attributed to it.

During the whole term of menstruation, women are weaker, more delicate, and susceptible of impressions: all their organs participate more or less in the affection of the uterus, and it is not difficult for an experienced observer to distinguish this state by the stroke of the pulse, but still more by the alteration of the face and tone of the voice. Women at that time require the greatest care; an unnecessary venesection, a purge, or other medicine improperly administered, may suppress the evacuation and occasion the most serious affections. Climate evidently influences the duration and quantity of the menses, since in Africa their discharge is almost continual, while in Lapland it takes place only two or three times in the year.

We shall not enter at large into the different explanations that have been given of this phenomenon. Some have attributed it to the depending situation of the uterus, without considering, that, according to their hypothesis, menstruation should have been effected from the soles of the feet! Dr. Richard Mead thought that it depended on the influence of the moon over the female system: but, in that case, why is it not subject to the moon's phases? Those who have judged the cause to exist in general or local plethora, by admitting this explanation have only increased the difficulty; for it will then be asked, What are the causes of this plethora? But if this opinion were founded on truth, nervous and debilitated women ought not to menstruate, and observation proves that they have this excretion in great abundance. Should menstruation be attributed to an acquired habit?

Has the problem been solved by saying that all the secretory organs of woman are too weak to evacuate the superfluous part of her humours, which rendered a new emunctory necessary? Is not the effect here taken for the cause? Does not this small quantity of liquid carried from the blood arise from this fluid being able to evacuate itself by the uterus? We must remark in a general sense, that the periodical flow of the menses seems to abstract females from many inconveniences that are prevalent in our sex, as the gout and calculous affections, so unusual in them, and so frequent in us. Nor can we omit distinguishing in the menses an important use relative to conception. Does not the uterus seem disposed by them to this act? (CXLIX.) (The generality of female quadrupeds have their sexual parts moistened with a reddish lymph during the term of salaciousness.) Was it not necessary for this organ to be accustomed to receive a great quantity of blood, in order that the state of pregnancy which requires this afflux might not occasion changes prejudicial to the whole system of vital functions?

The menstrual evacuation is suspended during pregnancy, and also in the first months of giving suck, although the latter rule admits of numerous exceptions. In our climate it ceases from the fortieth to the fiftieth year, sometimes sooner, seldom later; although I have now under my notice an example in a woman seventy years old, who has not yet ceased to menstruate, which is a fact not more surprising than those that afford proofs of a commencement of this excretion in the early years of life. When the period of the menses is past, the breasts become flaccid, the fleshy contour (*embonpoint*) of the body diminishes, the skin forms wrinkles, loses its softness and colour. This cessation is the cause of a great number of diseases observed at this age, called the *turn of life*, which are fatal to a great number of women: but it is also observed, that when this dangerous time has passed, their life is more secure, and a probability exists of its being protracted beyond that of a man of equal age.

Virility or adult Age.

CLXXII. This succeeds to adolescence or youth, and its commencement may be fixed from the twenty-first to the twenty-fifth year. All increase of the body in height has then ceased; the epiphyses are all completely cemented to the bodies of bones. But if man no longer grows taller, he extends in every other dimension. All the organs acquire a remarkable degree of firmness, solidity, and consistency. The same effect takes place in the intellectual and moral faculties. The dominion of the judgment succeeds that of the imagination. Man is capable of performing all the duties of a family and of society. This period of his life, described by the name of mature age, extends to the fiftieth or fifty-fifth year in men, but not much beyond the forty-fifth in women, in whom it begins rather earlier. During this long interval men enjoy all the plenitude of their existence.

Although in general it may not be difficult to distinguish, at first sight, a man of five-and-twenty from one of fifty years of age, yet the differences that characterize them, arising from the quantity and colour of the hair, and muscular power, are neither very numerous nor very essential.

Let us take the advantage in this age, in which the characters of the human species, that during infancy and adolescence were only slightly cast, are now fixed with more stability, to sketch the traits of the races and of individuals.

Temperaments, Idio-syncrasy, or individual Peculiarity.

CLXXIII. The name of temperaments has been given to certain physical and moral differences that present themselves in man, and which depend on the diversity of the proportions and connexion between the parts forming their organization, as well as the different degrees of energy relative to certain organs: besides, each individual has a particular manner of being, which distinguishes his temperament from that of every other, to which, notwithstanding, it may bear a very strong resemblance. These individual temperaments, the knowledge of which is of no small importance in the practice of physic, are called *idio-syncrasies.*

The predominance of this or of that system of organs modifies the whole animal economy, impresses obvious differences on the results of organization, and has not less influence over the moral and intellectual, than over the physical faculties.

If the heart and arteries, which cause the blood to circulate in every part, possess a predominant activity, the pulse will be strong, frequent, and regular; the complexion florid, the physiognomy animated, the stature elevated, the figure agreeable, though strongly marked, the fleshy parts firm, the deposition of adeps in the cellular structure (*embonpoint*) moderate, the hair of a flaxen, inclined to a chesnut colour; the nervous susceptibility acute, accompanied with a power of rapid succession (*successibility*); that is, persons in whom this excess of the circulatory system is observed, are easily affected by impressions from external objects, and quickly pass from one idea to another; the perception will be prompt, the memory tenacious, the imagination lively and luxuriant; they will be fond of the pleasures of the table and of love, possess a state of health seldom interrupted by slight diseases; and all their complaints, modified by the temperament, will have their principal seat in the circulatory system, as inflammatory fever, phlegmasiæ, hæmorrhage, &c.; and when in a moderate degree, shall terminate by the powers of nature, or require the use of remedies called antiphlogistic, among which bleeding is the principal. The ancients understood this disposition of the body by the name of *sanguineous* temperament; they considered it as produced by the combination of heat and moisture, and well knew that it chiefly existed in youth of both sexes; that it was increased in the spring, a season of the year which has been so justly compared to youth, by calling this age the spring of life.

In order that the specific characters of the temperament we have just described should present themselves to the greatest advantage, it is requisite for the modern perfection of the lymphatic system to coincide with the energy of the sanguineous system, so that both orders of vascular organs may be in a just equilibrium. The physical traits of this temperament exist in the beautiful statues of Antinous and the Apollo of Belvidere: the moral character is drawn in the lives of Mark Antony and Alcibiades. (See Plutarch.)

If men of this temperament accidentally devote themselves to works that require great exertion of the organs of motion, the muscles, moistened with fluids, and disposed to attain an extent proportionable to that of the sanguiferous system, increase in size, the sanguineous temperament suffers great modification, and there results from it the muscular or athletic temperament, remarkable for all external signs of vigour and of power. The head is very small, the neck very strong, particularly behind; the shoulders are broad, the chest large, the hips solid, the inter-muscular spaces strongly marked. The hands, feet, knees and all articulations not abounding in muscles, seem very small; the direction of tendons is seen under the skin covering them; susceptibility is not considerable, nor is perception acute: but, although difficult to be set into action, the athletic being, when once roused from his habitual tranquillity, surmounts every resistance. The *Farnesian Hercules* presents us with a model of the physical attributes of this particular constitution of the body. It would be difficult to find in history one example of a man having united to these corporeal powers a degree of intellectual faculties sufficient to acquire an immortal fame. To become distinguished in the career of sciences and the fine arts, an exquisite sensibility is requisite; a condition absolutely contrary to the extreme perfection of muscular masses.

If sensibility be both acute and easily excited, and in addition to these gifts, the capability of dwelling for a long time on the same object should exist; if the pulse be strong, hard, and frequent; the veins cutaneous, projecting; the skin rather brown, inclined to yellow; the hair black, the body moderately fleshy, the muscles firm and well marked, and the figure expressive; if these conditions exist, the passions are violent, the motions of the mind often abrupt and impetuous, the character steady and inflexible. Hardy in the conception of a project, constant and indefatigable in its execution; it is among men of this temperament that are found those who at different periods have governed the affairs of the world: abounding in courage, audacity, and activity, they have all signalized themselves by great virtues or by great crimes; they have been the terror or the admiration of the universe: such were Alexander, Julius Cæsar, Brutus, Mahomet, Charles XII. &c.

This temperament is also characterized by the premature appearance of the moral faculties. Those men whom we have just named, when emerging from adolescence, have conceived and executed enterprises that would have been worthy of their riper judgment. Since an excessive perfection of the liver, an obvious superabundance of the biliary juices, most frequently exist with this constitution of the body, in which the vascular system possesses the greatest energy, to the prejudice of the cellular and lymphatic systems, the ancients have denominated it the *bilious* temperament. The diseases to which individuals of this class are subject, sometimes present a derangement of the action of the hepatic organs joined with a change in the biliary fluid, as their principal character, and, at other times, as a collateral circumstance. Among the medicines employed to remedy these kinds of affections, evacuants, and particularly vomits, deserve to be in the greatest esteem.

If all the characters attributed to the bilious temperament be carried to the highest degree of intensity, and to this state be added great susceptibility, men are irascible, and launch into a passion from a trivial cause. Homer has thus described Achilles and some of his heroes.

When to this bilious temperament is superadded a morbid obstruction of some organ in the abdomen, or any derangement in the functions of the nervous system, and the vital functions are carried on in a weak and irregular manner; the skin is more deeply tinged, the countenance becomes uneasy and dismal, the bowels inactive, all excretions tardy, the pulse hard and habitually contracted. This general uneasiness (*mal-aise*) has an influence over the cast of ideas, the imagination becomes gloomy, the character suspicious. The very numerous varieties offered by this temperament, which was called by the ancients *melancholic;* the diversity of circumstances that may produce it, as hereditary diseases, long-continued sorrows, incessant study, the abuse of pleasures, &c. should induce us to adopt the opinion that Clerc has promulgated in the Natural History of Man in a state of Disease, in which work he considers the melancholic temperament less as a natural and primitive constitution, than as a morbid affection, either hereditary or acquired. The characters of Louis XI. and of Tiberius leave nothing more to be elucidated in the moral view of this temperament; but no person, perhaps, presents us with it in a greater degree of energy than the illustrious philosopher of Geneva. (See the Works of J. J. Rousseau. *Reveries du Promeneur solitaire, et les deux dernieres Parties des Confessions.)*

If the proportion of liquids be too considerable for that of the solids, this superabundance of fluids, which is always to the advantage of the lymphatic system, gives the whole body an increased bulk from the repletion of the cellular texture. The fleshy parts are soft, the skin fair, the hair flaxen or sandy, the pulse weak and slow, the figure plump and without expression, all the vital actions are more or less languid, the memory not tenacious, and the attention wavering. Those individuals who possess this temperament, to which the ancients gave the name of *pituitary*, or *phlegmatic*, and which is called by us *lymphatic*, because it really depends on the excess and activity of this system, have generally an insurmountable desire of indolence, they have a great dislike both to the exercise of the body and of the mind; we should not therefore be surprised at not finding any of this character among the illustrious men in Plutarch. As they were but little adapted for the transaction of affairs, they have never disturbed the face of the earth by their negotiations or their conquests. One of Cicero's friends, Pomponius Atticus, whose history has been transmitted to posterity by Cornelius Nepos, furnishes us with the model of a man who maintained a good understanding with all parties that raged in the Roman republic during the civil wars of Pompey and Octavius. Among the moderns, the indifferent Michael Montaigne, all of whose passions were so moderate that he reasoned on every thing, even a sentiment, equally inaccessible to love and to hatred, was completely pituitous. But in him the predominance of the lymphatic system was not carried to such a degree of ascendency as to prevent the existence of great nervous susceptibility.

This property, which causes us to be more or less sensible to impressions received by our organs, is weak in the pituitary system, almost non-existing in the athletic, moderate in those of a sanguine, and acute in the bilious temperament: when this property is excessive, it constitutes the *nervous* temperament, which is seldom natural or primitive, but most frequently acquired, and is dependent on a sedentary life, reiterated pleasures, exaltation of ideas kept up by reading works of the imagination (novels), &c. This temperament is distinguished by a slender habit, smallness of the muscles, that are soft and wasted, by the vivacity of sensations, the promptitude and variability of determinations and of judgment. Hysterical women, whose wishes are absolute but changeable, their sensibility very great, frequently present this state of the body with all its characters; sometimes, however, they are moderately fleshy, from a degree of plenitude of the lymphatic system being joined to an extreme predominance of the nervous system. Convulsive motions are not uncommon in these persons; and if it be considered, that, on the other hand, the athletic constitution is the direct opposite of the nervous, and gives a predisposition to tetanus, might it not be said that both extremes unite or produce the same effects?

Antispasmodic medicines succeed in the treatment of diseases of this system, which always more or less partake of the impression of the temperament. Stimuli, on the contrary, are more advantageous in those affections to which persons of a pituitary or lymphatic temperament are subject.

We shall conclude this dissertation on temperaments by observing, that, in strict truth, we are born with these peculiar dispositions of the body; but that, by education, manner of living, climate, or acquired habits, they become altered or totally changed. Besides, it is very rare to meet with individuals, who present us with every one of the characters assigned to the different temperaments in all their purity: the descriptions given are selected from a numerous collection of individuals who have striking resemblances to each other; their characters are mere abstractions, which are difficult to be realized, because all men are both sanguine and bilious, sanguine and lymphatic, &c. It is observed that the constitution called sanguine is the direct contrast of the melancholic, and never combined with it; the same diversity exists between the bilious and lymphatic; although it may happen that a man of sanguineous habit may become melancholic after a lapse of time; for man never remains in the state of nature, being acted on by every surrounding body: his physical qualities, if observed at distant periods of life, present as many differences as his character.

The climate exerts an obvious influence over the temperament. Thus the bilious is that of the greatest number of inhabitants of southern regions, the sanguine that of northern people, and the lymphatic is more prevalent in cold and damp countries, as Holland, &c.

Among the moderns, those who have modified and enriched the ancient doctrine of temperaments are Hallé, Cabinis, and Pinel. See their works.

Varieties of the human Species.

CLXXIV. The faculty of producing similar individuals, by copulation, is considered by naturalists as the surest character from which may be established the species in animals of red and warm blood. This power of perpetuating itself by a constant succession of beings, that resemble those from which they are produced, exists in all the races composing the human species, whatever be their diversity of colour, structure, and manner of living. Men, therefore, form but one species; and the differences presented according to the part of the globe they inhabit, can only constitute the races or varieties of them.

We admit, with Lacépède the worthy continuator of Buffon, four principal races of the human species, which like him we shall name the Arab-European, Mongol, Negro, and Hyperborean. A fifth might be added, formed by the Americans, were it not very probable that the new continent has been peopled by inhabitants, who coming from the old world either by the land of the southern hemisphere, or the immense archipelago formed by the islands of the Pacific Ocean, have been more or less altered by the influence of this climate and soil; so that they should not be considered as another race, but rather as a variety.

There is in fact this difference between varieties and races; the latter are supposed to require greater modifications, more essential differences, and changes that are not confined to the surface, but extend even to the structure of the body; on the other hand, to constitute varieties, it is only necessary that there should exist the effects of the superficial influence of climate on the integuments, which it tinges, and on the hair, which it renders long or short, curled or lank, coarse and hard, or soft like wool. A native of Abyssinia scorched by the heat of an atmosphere near the tropic, has a skin as black as the negro who is exposed to the rays of the sun under the equator; yet they cannot be classed together; it is not possible to consider them as forming one and the same race, since the Abyssinian, though in colour like the negro, resembles the European race by the contour of his face and the proportions of all his parts.

The characters of the Arab-European race, which not only comprehends the inhabitants of Europe, but also those of Egypt, Arabia, Syria, Barbary, and Ethiopia, are, the face oval or nearly oval in a vertical direction, the nose long, the cranium projecting, the hair long and generally lank, the skin more or less white. These fundamental characters are in no part so well marked as in the north of Europe. The people of Sweden, Finland, and Poland, afford a kind of prototype of the race: their stature is high, their skin of a perfect whiteness, their hair long, smooth, and of a light flaxen colour: the iris is mostly blue. The Russians, English, Danes, and Germans, deviate from this primitive type: the teint of their skin is of a less pure whiteness, and their hair of a darker flaxen. The French seem to hold the medium between the inhabitants of the north and of the south of Europe. Their skin is shaded with darker teints, their hair is more curled and less flaxen than chesnut and brown. The Spaniards, Italians, Greeks, European Turks, and Portuguese, have a deeper tinge; their hair is mostly black: and lastly the Arabs, Moors, and Abyssinians have black hair, more or less curling, the skin of a darker shade, and they may be considered a link between the Arab-European and negro race, which latter, however, differs from the former by the flatness of the forehead, smallness of the cranium, obliquity of the line projected along the face, the thickness of the lips, the blackness and density of the skin, which is fat and appears oily, the hair shorter, finer, curled, and woolly.

The Mongol race has the forehead flat, the cranium not very prominent, the eyes directed a little obliquely outwards, the cheeks projecting; and the oval formed by the face, instead of being from the forehead to the chin, is from one cheek to the other. The Chinese, Tartars, the inhabitants of the peninsula of the Ganges and of other countries in the East Indies, of Tonquin, Cochin-China, Japan, the kingdom of Siam, &c. &c. constitute this race, which is more numerous than any other, seems to be the most ancient, and is extended over a greater surface than the Arab-European or the negro race. It reaches from the fortieth to the sixtieth parallel, and occupies an arc of the meridian of about 75 degrees; that inhabited by the European is only 50; and the negro race, placed between the tropic of Cancer and of Capricorn, is circumscribed between an arc of from 30 to 35 degrees. (Lacépède, Geographie zoologique.)

The Hyperborean race, situated to the north of both continents near the polar circles, formed by the Laplanders, Samoiedes, and the inhabitants of Greenland, is characterized by a flat face, squat body, and very short stature. This portion of the human species is invested with its distinctive characters by the influence of climate. Nature, from a continual struggle against the inclemency of the weather and the destructive action of severe frost, is confined in her actions, contracted in every direction, and can only produce beings whose physical imperfection explains their state, which is bordering on barbarity.

The small progress of negroes in the study of sciences and in civilization; their decided taste and singular aptitude for all the arts that require more address than understanding and reflection, as dancing, music, fencing, &c.; the form of their head, which is in a medium between the European and ourang-outang (Cuvier, Leçons d'Anatomie comparée); the existence of intermaxillary bones at an age when in us the traces of their separation are completely obliterated; the high situation and smallness of the calf of the leg, &c. have been advanced as arguments, which, however, are less solid than specious, by those who have endeavoured to degrade this portion of the human species, with a view of justifying the commerce made of them by civilized nations, and the slavery to which they are reduced.

Without admitting this position, believed by the avarice of riches, we cannot but allow that the differences in organization induce an obvious inequality in the perfection of the moral and intellectual faculties. This truth will be completely elucidated if we can point out their moral differences to be equally real and strongly marked as the physical characters of the human races that have been just recapitulated; oppose European activity, versatility, and restlessness, to Asiatic indolence, phlegm, and patience; examine what effects may be produced on the character of nations by fertility of the soil, serenity of the atmosphere, and mildness of the climate; show by what obligation of physical and moral causes the influence of custom has so much power over Eastern people, that in India and China we find the same laws, manners, and forms of worship as existed long before the commencement of our era; investigate by what singularity, worthy of the reflection of philosophers and politicians, these laws, manners, and religions have suffered no alteration amidst the revolutions that have so frequently overturned those rich countries, which have been several times conquered by the warlike Tartars; demonstrate that ignorant and ferocious conquerors, by the irresistible ascendency of wisdom and information, have adopted the customs of the nations they have subjugated; and prove that the stationary state of the arts and sciences, in people who have enjoyed the benefits of society and the advantages of civilization, so long before us, is not to be so much attributed to the imperfection of their organization as to the humiliating yoke of a religion abounding in absurd practices, and which makes learning the exclusive appendage of a privileged cast (Sur la Religion des Brames et les Coutumes Indiennes, l'Histoire philosophique et politique, &c. par G. Thomas Raynal). Such an undertaking however would exceed the limits of this work, and does not immediately belong to our subject.

The *Albinos* of Africa, the *Cagots* of the Pyrenees, and the *Cretins* of the Valais country, cannot be given as varieties of the human species. These are infirm, weak, and degraded beings, incapable of reproducing their like, and carrying on a miserable existence among an healthy, vigorous, and robust population.

We shall not give credit to what some travellers have written on the existence of giants on the coasts of Magellan. The Patagonians, whose stature has been so variously reported, are well-formed men, and seldom exceed us in height above 9 or 12 inches. The Laplanders are about as much under our standard, and are not more than from 4 to 4 feet and a half. Some individuals become so much taller than usual, as to deserve the name of giants; and others, contracted in every dimension, offer an example of pigmies. Among the latter may be reckoned Bébé, the dwarf of Stanislaus king of Poland: and in the former class may be considered Goliah, mentioned in the 4th verse of the 17th chapter of the first book of Samuel; the king Og, quoted in the second verse of the 3d chapter of Deuteronomy; and several others, whose stature was between six and ten feet (from 1 metre 948 millimetres, to 3 metres 247 millimetres).

On advanced Age and Decrepitude.

CLXXV. The human body, which from the twentieth year of its existence has ceased to grow in height, augments in every other dimension during the twenty-five succeeding years; after which, instead of increasing, it diminishes, and daily loses the power it had acquired. The decrease follows the same progression as the growth: the former is not more rapid than the latter, since man, who requires from thirty to forty years to arrive at the apogeum of his vigour, employs the same space of time in descending to the grave, when no accident hastens his death. The whole volume of the body diminishes, the cellular structure collapses, the skin wrinkles, particularly in the forehead and face; the hair turns gray, and afterwards white; organic action becomes languid; the humours are more disposed to putrefaction (Hunter); all diseases from debility are mor severe and frequent.

The duration of life may be estimated by the time employed in growth. A dog, that is only two or three years in growing, seldom lives more than ten or twelve years. Man, who occupies a period of thirty years in corporeal increase, lives to the age of eighty or an hundred years. Fish exist for centuries, because a great number of years are required for the perfection of their growth.

Decay *(caducité)* succeeds old age. The sensibility of organs is blunted; the moral and physical powers perceptibly diminish; man ceases to be affected in the same manner by surrounding bodies; he forms incorrect judgments on circumstances that arrest his attention, because, self-love preventing him from estimating the changes he has undergone, he is more inclined to attribute the difference that exists between the sensations he now feels and those experienced in his youth *(laudator temporis acti)* to an universal degeneration of things. Digestion is ill performed, the pulse weak and tardy, absorption difficult by the almost total obliteration of the lymphatic vessels and the induration of conglobate glands; the secretions are languid, and nutrition is imperfect. The old man has a degree of slowness in all his actions, and stiffness in all his motions: his hair falls off, his teeth drop from their sockets, the cartilages ossify; the bones form irregular depositions and anchyloses with each other, their internal cavity increases (Chaussier); all the organs become hard, the fibres more dry and contracted. We are not, however, to conclude that all the soft parts are rendered more compact; some of them, for example the muscles, as observed by Haller, soften, and seem to incline towards a speedy dissolution by losing their vital properties (*Non ergò in solâ rigiditate causam senii mortis oportet ponere; nam ex defectu irritabilitatis plurimi in senibus musculi languent, mollesque pendent.* Elem. Phys. tom viii. in 4to, lib. 30); nor that death is totally dependent on the accumulation of phosphat of lime, which is deposited in all the organs, ossifies the vessels, and impedes the actions of the animated machine. If this terrene matter destroys all the parts of the animal system, it is on account of the digestive powers being gradually weakened, and ceasing to impress alimentary substances with their proper character. The exuberance of calcareous salts is consequently not so much a cause as an effect of the successive destruction of the vital powers; yet an universal rigidity will be estimated as one of the principal causes of death, if it be considered that women, whose organs are naturally more soft, are longer in arriving at this state, more lively than men, and furnish more examples of longevity. The body, then, says the eloquent M. Buffon, gradually dies; life is extinguished by successive shades, and death is only the last term of this succession of degrees (*la dernière nuance de la vie*).

We are of opinion that it is useless seriously to refute those who have thought it possible, by the use of different means, to obviate this inevitable term of our existence, and to prolong life far beyond its natural bounds. These long-forgotten pretensions have reappeared since the astonishing discoveries of modern chemistry. All such errors have been anticipated and refuted by the immortal author of Natural History.

"The causes of our destruction are necessary, and death is inevitable. It is no more possible for us to avert the fatal term, than to change the laws of nature. The ideas that some visionary men have had on the possibility of perpetuating life by remedies, would have perished with them, if self-love did not always augment credulity to such a degree, as to persuade itself of what is even the most impossible, and to doubt of that which is most true, real, and constant. The panaceum, whatever might have been its composition, the transfusion of blood, and other means that have been proposed to renovate or immortalize the body, are at least as chimerical as the fountain of youth is fabulous." Buffon, Hist. Nat. in 12mo. tom iv. p. 355.

The reader will not consider it an intrusion if we transcribe, in addition to the above elegant piece, a passage from Alibert's Dissertation on Old Age, in which the same ideas are described in the most lively and affecting colours:

".....Yet what can be said? The precautions of our art are of no avail against a common law imposed on all the beings of the universe. By a continued regimen, by assistance long and attentively maintained, we may, doubtless, rekindle the sparks of life for some instants; but it concludes by being extinguished like an expiring lamp, that is consumed for want of nourishment. Time is as eternal in his destructions as nature is in her creations. The anchor is not cast in the river of life, says a celebrated modern author; it carries away those who struggle against it as well as those who go with the stream. Alas! why is it necessary for man to advance with so much reluctance towards the certain termination of his cares and his errors?.....Why should he weep at his setting, as he had wept at his dawning?.....Let us imitate the example of so many wise old men, who honoured antiquity: Hesiod, Homer, Democritus, Plato, and those renowned patriarchs, who formerly inhabited the country of Palestine, saw death approaching without fear, and retired in peace to the bosom of their ancestors. Anacreon, when on the brink of the grave, still continued to sport with the Graces: a pure and innocent joy animated the winter of his age, and crowned his silver locks with roses. Let us therefore endeavour to strew some flowers over the thorns of life, but do not let us possess the senseless pretension of perpetuating its duration. Galen, who taught the art of growing young, did not prevent the wrinkles of old age from furrowing his forehead and cheeks. The potable gold and elixirs of Paracelsus could not secure him from a sudden and premature death. The unhappy metamorphose of Tithon, mentioned in fabulous history, is a true emblem of the impossibility of resisting the injuries of years."—Memoires de la Soc. Med. d'Emulation, tom i.

On Death.

CLXXVI. Man is deprived of the faculty of reproducing himself long before the natural termination of his existence; and in the more or less protracted agonies that serve as a passage between life and death, the organs of the senses are first affected and rendered insensible to every kind of impression; the eyes become dim, the cornea flaccid, the eyelids closed, the voice is stifled, the limbs and trunk of the body are without motion, yet respiration and the circulation continue to be performed; the latter terminates first in the vessels distant from the heart, then in those nearer, and the blood ultimately ceases to flow in the trunks immediately connected with this organ. Respiration is gradually retarded, and at last entirely suspended; after a strong expiration, the lungs no longer give passage to the fluid brought from every part of the body to the heart. This liquid remains in the right cavities of this organ (*ultimum moriens*), which, from distention by the blood there accumulated, acquires a capacity above that of the left cavities, that empty themselves more or less completely.

Does this powerful and last expiration, often accompanied with a sigh, depend on the spasmodic action of the expiratory muscles, or is it not rather to be attributed to the reaction of the elastic parts forming the thorax; a reaction that suddenly ceases to be counterbalanced by the vital powers? (See Sabatier's Memoir on the unequal Capacity of the Heart and pulmonary Vessels).

Such is the mechanism by which a natural death is effected. The brain had already ceased to receive from the debilitated heart a quantity of blood sufficient to maintain sensibility; a small degree of irritability still remained in the muscles of respiration; this is consumed, and the circulatory motion of the blood is arrested with the life of all the organs which this liquid had chiefly maintained.

As to accidental death, it is always occasioned by an interruption of the action of the heart and of the brain; for the death of the lungs brings on the cessation of life in the rest of the body merely by preventing the action of the heart, and destroying its influence over the brain.

The Period of Death.

CLXXVII. This is nearly the same in all men, whether they live near the poles or under the equator, whether they make use of vegetables or live exclusively on animal food, whether they lead a laborious life or consume their existence in a shameful idleness or a culpable sloth. We seldom find individuals prolong their existence beyond the hundredth year; yet we are in possession of several observations of men who have lived much longer; and in the Philosophical Transactions there is an account of a man who attained his 165th year. The greater number, however, do not complete their century, and natural death happens from the age of 65 to 100.

The difference of climates, which has no effect on the duration of life, possesses a very manifest influence over the rapidity of growth. Puberty, virility, and old age, take place much sooner in warm than in cold countries: but this perfection, that shortens the early distinctions of life, proportionably augments that of old age.

The Probabilities of human Life.

CLXXVIII. Man dies at every age; and if the continuance of his life exceed that of animals, the multitude of diseases to which he is exposed renders it less certain, and occasions a smaller number to arrive at the natural term of their existence. Men have endeavoured to obtain a knowledge of the probabilities of life, that is, to prove by observation how many years a person of a given age may yet expect to survive. From the most careful investigation of facts concerning the age in which the greatest number of individuals have died, and by a comparison of the deaths with the births, it has been decided that about a fourth part of the children die before eleven months, a third before twenty-three months, and nearly half before they have reached eight years. Two thirds of mankind die before the thirty-ninth year; three fourths before the fifty-first: so that, according to Buffon's observations, out of nine infants one only attains to the seventieth year, one in thirty-three lives to eighty, one in two hundred and ninety-one carries on the functions of life to the ninetieth year; and, lastly, in eleven thousand nine hundred and ninety-six, only one human being completes a century from the first moment of his existence.

According to this author the middle term of life is eight years: in proportion as the child advances in age its existence becomes more probable, and after the first year it may be reasonably expected to live to the thirty-third. Life is rendered gradually more secure to the seventh year, when the child that has passed over the dangers of the first dentition may expect to survive to the age of forty-two years and three months. After this period (seven years) the probabilities, hitherto gradually increased, suffer a progressive diminution and decrease, so that the child at fourteen years can only look for thirty-three years and five months more; the adult at thirty years twenty-eight more; and, lastly, the person who has attained the eightieth year, but one more. From the eighty-fifth to the ninetieth the probability is stationary; but after having passed this time, existence becomes very doubtful, and the individual is carried toward his end. Such is the medium result of observations and calculations on the different degrees of the probability of human life, made by Halley, Grant, Kersboom, Wargentin, Sympson, Deparcieux, Dupré de St. Maur, Buffon, D'Alembert, Barthez, and Mourgues, who has just published his observations on this subject, that were made for a succession of years at Montpellier with the most rigid exactness.

We should enter into more minute details on this subject, were it not rather in the department of the political than of the animal economy.

Putrefaction.

CLXXIX. The history of life should here close; yet if attention be paid to the changes that bodies which have possessed it experience after its privation, they will be found to elucidate materially its means, purposes, and nature; the necessity of taking a cursory glance of the phenomena that accompany the decomposition of the body will be perceived, which is not out of the department of physiology until its appearance can no longer revive the idea of its former state, and until after the last lineaments of organization are completely obliterated.

As soon as life abandons the organs, they become totally influenced by physical laws, to which all inorganized bodies are subjected: an intestine motion takes place in their substance, and their moleculæ have a tendency to separate from each other, that is stronger in proportion to their excess of composition. Chemistry teaches us that the capability of change in bodies is in a direct ratio with the multiplicity of their elements; and that the existence of an organized being after death is protracted so much the longer, as its constituent principles are less numerous and volatile.

In order to establish putrefaction in the human body, it should be absolutely deprived of life; for the powers that maintain vitality form the most powerful antiseptic; and it might be advanced that this state is nothing but a permanent contest against physical and chemical laws. This vital resistance, expressed by the ancients when they affirmed that the laws of the little world (microcosm) were in perpetual contradiction to those of the great world, which ultimately overcame it: this power constantly reacting is manifested by life, which may be therefore defined *the resistance opposed by organized bodies to causes that continually tend to destroy them.* Let these phenomena be examined, and it will be seen that all are directed to the end of its preservation, and only perform this task by keeping up a continual struggle against the laws that govern inorganized bodies.

We should be, perhaps, astonished to find in death a just idea of life, if we did not know that it is only by comparing that we are enabled to distinguish, judge, and understand.

Putrefaction is only begun, carried on, and completed in dead substances. A gangrened limb loses its vitality before putrefaction takes place; and if nature preserve a power sufficient to counteract this contrary tendency, she forms a line of boundary between the living and dead parts by an inflammatory circle. Life and putrefaction are, therefore, two ideas absolutely contradictory to each other; and when, in particular diseases, a certain tendency of the solid and fluid parts to spontaneous decomposition is observed, this tendency to putridity ought not to be confounded with putridity itself.

Several conditions are requisite for putrefaction to be established in the human body when destitute of life: 1st, a mild temperature, that is above 10 degrees of Reaumur's thermometer; 2d, a certain state of humidity; 3d, the contact of air: but this last condition is not so indispensable as the others, since bodies go into decay in a vacuum, although more slowly than when exposed; the air, consequently, only facilitates decomposition by volatilizing the elements which rise in vapours. On the contrary, an icy coldness, or an excessive heat approaching ebullition, prevent it; the former by condensing the parts, the latter by depriving them of this humidity, the absolute privation of which explains the preservation of Egyptian mummies.

The phenomena of putrefaction, resulting from a series of particular attractions, are variously modified according to the animal matters that are subjected to it, the medium in which it is effected, the different degrees of temperature and humidity, and even according to its different periods. Notwithstanding these numerous varieties, it may be said that all animal substances in general at first exhale a musty or cadaverous odour, soften, increase in size, become heated, change their colour, turn green, then blue, and lastly a blackish brown; a great number of gaseous matters are at the same time disengaged, among which the ammoniac is the principal, both on account of its quantity, and because animal matter begins to furnish it from the instant its alteration commences to the period of its most complete dissolution. The penetrating and septic odour diffused from dead bodies is to be attributed to this gas.

Towards the termination of putrefaction some carbonic acid gas is disengaged, which, combining with the ammoniac, forms a fixed and crystallizable salt: to these products are added hydrogen, united with phosphorus, sulphur, azot, and carbon, and all things that can result from their respective combinations. Lastly, when animal matter is reduced to a residuum, containing oils and different kinds of salts, it forms a soil from which plants draw the principles of a very rich and vigorous vegetation. The bones are the least alterable parts of the organized machine, but ultimately become dry by the slow combustion of their fibrous part, and the evaporation of the medullary fluids: at last, when reduced to an earthy skeleton, they fall to dust, and are dissipated on opening the tombs.

Thus every thing that can renew the idea of our material existence is at last effaced.

Putrefaction, considered in a philosophical point of view, is only the method employed by nature to return our organs that are deprived of life to a more simple composition, in order that their elements may be employed for new creations. (*Circulus æterni motus.* Beccher, *Physica subterranea.*)

Nothing, therefore, is better proved than the metempsychosis of matter; which gives us reason to believe that this religious dogma, like the generality of tenets and fabulous conceptions of antiquity, is only a mysterious veil, ingeniously thrown by philosophy between nature and the lower order of people.

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