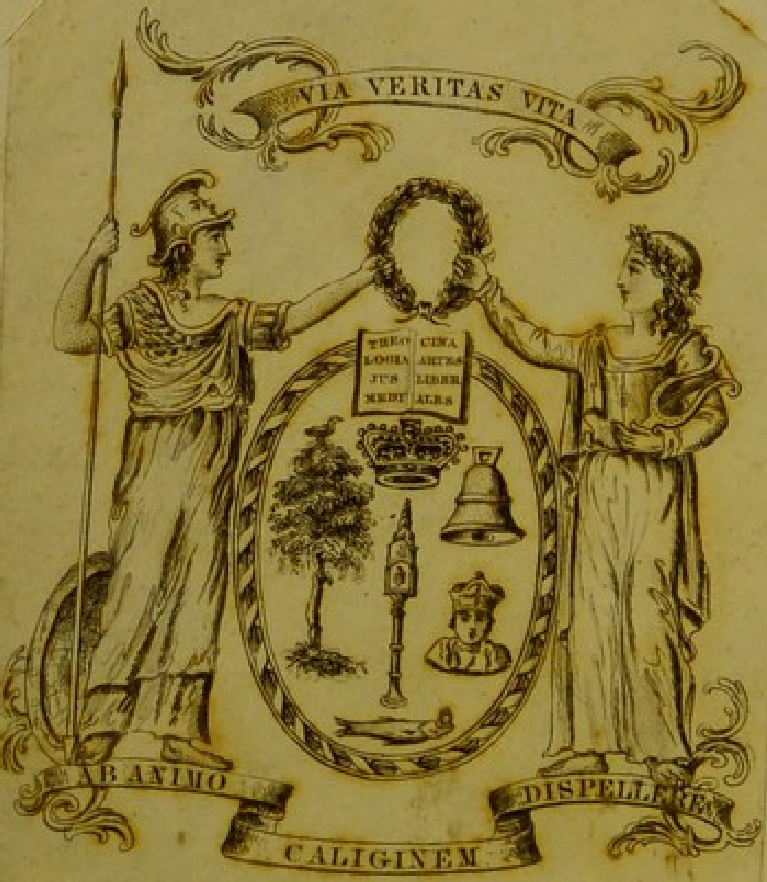
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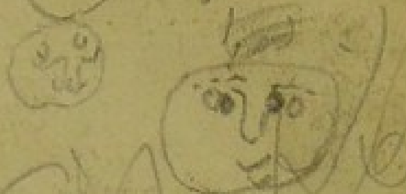

AN

ELEMENTARY SUMMARY

OF

PHYSIOLOGY.

BY F. MAJENDIE,

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TRANSLATED FROM THE FRENCH

BY

A MEMBER OF THE MEDICO-CHIRURGICAL SOCIETY.

VOL. I.

CONTAINING PRELIMINARY OBSERVATIONS, THE HISTORY OF SIGHT, HEARING, SMELL, TASTE, TOUCH, INTELLECT, INSTINCT, THE PASSIONS, VOICE, ATTITUDES AND MOTIONS.

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TO

Astley Cooper, Esq. F. R. S.

SURGEON TO GUY'S HOSPITAL,

TEACHER OF ANATOMY AND SURGERY IN THE

UNITED HOSPITALS, ETC.

THIS TRANSLATION

IS INSCRIBED

BY HIS FRIEND

The Translator.

THE TRANSLATOR'S PREFACE.

THE following is a most admirable production, infinitely superior to every other work upon Physiology, except, perhaps, Blumenbach's Physiological Institutions, and well deserving to be in the hands of every member of the profession.

These reasons induced the Translator to undertake a task for which neither his inclination nor his engagements disposed him.

As his object was to prevent the Work from suffering by being translated by some hired writer, he trusts that the possession of the present Translation will be equal to the possession of the original Work.

London, 1st September, 1816.

PREFACE.

EVERY natural science may exist under two different forms, 1. systematic; 2. theoretical.

Under the systematic form the science is founded upon some gratuitous suppositions, some principles established *a priori*, to which known facts are attached so as to be explained. If a new fact is discovered, which does not accord with the fundamental principle, this is modified till it furnishes an explanation which gives satisfaction: if the learned give themselves up to the labour of experiment, it is always with the intention of confirming the system which has been adopted: every thing that can tend to overthrow it is neglected or unperceived; they seek after what ought to be, not what is; in short the synthetic course is completely followed, in which they descend from hypotheses to facts, without rising to any of the general consequences which ought to be had in view in inquiries after truth.

When this form is observed, it is almost impossible for a natural science to make real progress.

The theoretic form of natural sciences is diametrically opposite to this. Facts, and facts alone, constitute the foundation of the science, under this form: the learned endeavour to verify them, and to multiply them as much as possible, and afterwards study the relations of the different phenomena, and the laws to which they are subject. When they give themselves up to experimental researches, it is with the view of augmenting the number of ascertained facts, or to discover their reciprocal relation; in a word, the analytical course is followed, which alone can lead to truth. By following this method, the sciences increase, if not rapidly, at least surely, and we may hope to see them approach perfection.

With some exceptions, all the natural sciences were systematic before the age of Galileo and Bacon. From this period, and partly from the influence of the works of the illustrious chancellor, most of the natural sciences underwent a fortunate change; from being systematic and synthetic they became theoretic and analytic; and from this time have increased and grown more perfect from day to day.

It is painful, but at the same time necessary to mention, that in the midst of this general progress of the sciences, physiology, so important a branch of natural knowledge, has hitherto preserved its systematic form. If we attentively examine the manner in which it is treated in the best works, we shall find it founded upon mere suppositions, to which every one attaches at pleasure, the numerous phenomena of life, thinking that he is explaining them satisfactory. What in fact are the *vital* or *animal* spirits of the ancients, the *faculties* of Galen, the *moving* and *generating principle* of Aristotle, *the archeus, the vital principle, power* and *properties*, &c. which have been successively adopted to explain the animal functions, but arbitrary suppositions, which served through many ages to conceal the absolute ignorance in which we always have been, and perhaps always shall be, respecting the cause of life?

What is the consequence of this? It is that physiology, brilliant as it may appear in the writings of the present day, and notwithstanding the improvements supposed to be made in it by men of great talents, is still in its infancy. The science must really quit this distressing state of imperfection. To effect this, the first object is to change the form, and consequently the course, which it has hitherto pursued; it must take the analytic course and the theoretic form; then only will it improve and be upon a footing with the most advanced natural sciences.

My principal view in writing this work is to contribute to effect this important charge: I have at least exerted all my efforts to present the science under the theoretic form, by following the analytic method in the exposition of facts.

There will therefore above all be found in this work facts which I have directly verified as much as was in my power, either by observation upon the healthy or diseased subject, or by experiments upon living animals. Among these facts will be found many which are new.

I have not, however, neglected the possible and useful applications of physics, of mechanics, chemistry, &c. to the phenomena of life; perhaps they will be different from those which have been hitherto offered, for I have neglected nothing to ascertain their exactness.

Human physiology is the only subject which I have wished to consider; general physiology, which comprehends the history of all living bodies, animals and vegetables, is not at present sufficiently advanced to form a complete body of doctrine; and what we do know is not of a nature to form a part of an elementary work.

I must, while concluding, remark that this book is altogether intended for medical students. If whatever is positively known in physiology is found expressed in clear and simple terms, I shall have accomplished my object.*

* I am eager publicly to return thanks at this opportunity to my friend, Dr. Edwards, who has assisted me in all my experiments, and whose great information and judicious mind have been of great advantage to me in arranging the work.

CONTENTS.

AN ELEMENTARY SUMMARY OF PHYSIOLOGY

General Physiology is that natural science which has for its object the knowledge of the phenomena peculiar to living bodies. It is divided into *vegetable physiology*, which regards vegetables; into *animal* or *comparative physiology*, which regards animals; and into *human physiology*, the special object of which is man. It is of the latter that we propose to treat in this work.

PRELIMINARY OBSERVATIONS.

OF BODIES AND THEIR DIVISION.

Whatever is capable of acting upon our senses we call *body*.

Bodies are divided into ponderable and imponderable. The former are those which can act upon many of our senses, and whose existence is clearly demonstrated; such are solids, liquids, and gases.

The latter are those which act in general but upon one of our senses, whose existence is not demonstrated, and which perhaps are only powers or modifications of other bodies; these are caloric, light, the electrical and magnetic fluids.

Ponderable bodies are endowed with *common* or general properties, and with particular or *secondary* properties.

The general properties of bodies are extension, divisibility, impenetrability and mobility.

A ponderable body, whatever it may be, always presents these four properties united.

The secondary properties are distributed among different bodies: such are hardness, porosity, elasticity, fluidity, &c.; by their combination with the general properties they constitute the condition of bodies. Bodies change their condition by acquiring or losing these secondary properties; for instance, water may exist under the form of ice, fluid, or vapour, although it is always the same body. To exist successively under these three forms, it has only to acquire or lose some of its secondary properties.

Bodies are simple or compound. Simple bodies are seldom found in nature; they are almost always the production of art, and indeed they are termed *simple*, merely because art has not been able to decompose them. The bodies at present regarded as simple, are the following: oxygen, chlorine, iodine, fluorine, sulphur, hydrogen, borium, carbon, phosphorus, azote, silicium, zirconium, aluminium, yttrium, glucinium, magnesium, calcium, strontium, barium, sodium, potassium, manganesium, zinc, iron, tin, arsenic, molybdenum, chromium, tungstenium, columbium, antimony, uranium, cerium, cobalt, titanium, bismuth, copper, tellurium, nickel, lead, mercury, osmium, silver, rhodium, palladium, gold, platina, iridium.

Compound bodies are met with every where: they constitute the mass of the globe and of all the beings which inhabit its surface. Certain bodies have a constant composition, i. e. one which is not changed by circumstances; the composition of others, on the contrary, changes every instant.

This difference among bodies is extremely important, and naturally divides them into two classes: bodies whose composition is constant are called *brute, inert, inorganic* bodies; those whose elements are continually varying are called *living, organised* bodies.

Brute and organised bodies differ first in form, secondly in composition, and thirdly in the laws which govern their changes of condition. The following table presents the most striking differences.

Differences between brute and living Bodies.

Brute bodies.	Living bodies.
FORM.	
Angular form. Indeterminate volume.	Rounded form. Determinate volume.
COMPOSITION.	
Sometimes simple. Seldom formed of more than three elements. Constant. Each part able to exist independently of the others. Capable of decomposition and recomposition.	Never simple. At least four elements, Often eight or ten. Variable. Each part more or less dependent upon the whole. Capable of decomposition, but not of recomposition.
LAWS WHICH GOVERN THEM.	
Subjected entirely to attraction and chemical affinity.	Partly subjected to attraction and chemical affinity. Partly subjected to an unknown power.

Living bodies are divided into two classes; the one comprehends vegetables, the other animals.

Differences between Animals and Vegetables.

VEGETABLES.	ANIMALS.
Fixed to the soil.	Move on the surface of the soil.
Have carbon for the principal base of their composition.	Have azote for the base of their composition.
Compounded of four or five elements.	Often compounded of eight or ten elements.
Find and take their nourishment ready prepared around them.	Have to act upon their nourishment to render it fit for its purposes.

Elements which enter into the Composition of the Bodies of Animals.

The consideration of the elements which can enter into the composition of the bodies of animals, is useful not only in a physiological point of view; it furnishes many important physiological data to the physician for the treatment of diseases. These elements are solid, liquid, gaseous, and incoercible.

Solid Elements.

Phosphorus, sulphur, carbon, iron, manganese, potass, lime, soda, magnesia, silex and alumine.

Liquid Elements.

Muriatic acid; water, which in this case may be considered as an element, constitutes three fourths of the organization of animal bodies.

Gaseous Elements.

Oxygen, hydrogen, azote.

Incoercible Elements.

Caloric, light, the electric and magnetic fluids.

These different elements, combined, three and three, four and four, &c. according to laws yet unknown, form what are called *the immediate principles of animals.*

Immediate Principles, or Materials of Animals.

The immediate principles of animals are distinguished into azotised and unazotised.

The azotised principles are, albumen, fibrine, gelatine, mucus, cheese, urea, uric acid, osmazome, the colouring principle of the blood.

The unazotised principles are acetic acid, benzoic acid, lactic acid, formic acid, oxalic acid, rosacic acid, sugar of milk, sugar of diabetes, picromel, the yellow colouring principle of the bile and of other liquids and solids which become yellow accidentally, the vesicating principle of cantharides, spermaceti, biliary calculus; the odorous principles of musk, castor, civet, &c. which are scarcely known but by their power of acting upon the smell.

Animal fats are not simple immediate principles. M Chevreuil has proved that human fat, that of pork, mutton, &c. are principally formed of two fatty bodies which present very different characters, and which may be readily separated.

The butter of the cow is not a simple principle; it contains acetic acid, a yellow colouring principle, and an odorous principle, which is obvious in fermented cheeses.

Among these materials we must not include adipocere, which is found in bodies long buried in the earth: it is composed of margarine, of acid fluid fat, of an orange colouring principle, and of an odorous principle. This must not be confounded with the spermaceti of the whale, and with the biliary calculus, which indeed are very different from each other. M. Chevreuil has proved that it does not contain a single principle analogous to them.

Organic Elements.

These materials are in their turn combined, and from their combination result the organic elements, which are either solid or liquid. We know nothing of the laws or powers which govern these combinations.

Organic Solids.

The solids have sometimes the form of canals, sometimes of plates or lamellæ, sometimes of membranes. In man, the whole weight of the solids is in general eight or nine times less than that of the fluids. This proportion varies, however, according to many circumstances.

The ancients thought that all the organic solids might be ultimately reduced to a simple fibre, which they supposed to be formed of earth, oil, and iron. Haller, who admitted this idea of the ancients, allows that this fibre is visible to the eyes of the mind only; he might as well have said that it has no existence, as every one at present is convinced.*

The ancients besides admitted secondary fibres, which they supposed to be formed by particular modifications of the simple fibre. Hence the *nervous* fibre, the *muscular, parenchymatous* and *osseous.*

M. Professor Chaussier has in modern times proposed to admit four kinds of fibres, which he terms *laminary, nerval, muscular* and *albugineous.*

Science was nearly in this state when M. Pinel conceived the happy idea of distinguishing the organic solids, not by fibres, but by tissues or systems. Upon this division he founded many orders of diseases, but particularly

* Invisibilis est ea fibra; solâ mentis acie distinguinus.

the phlegmasiæ. Bichat seized this fine conception, and applied it to all the solids of animal bodies : the work which he wrote on this subject is his highest title to glory.* M. Dupuytren has perfected Bichat's classification ; M. Richerand has also pointed out several of its defects.† This is the classification of tissues, rectified according to the views of M. M. Dupuytren and Richerand :

1		cellular.	
2		vascular.	arterial. venous. lymphatic.
3		nervous.	cerebral. gangliar.
4		osseous.	
5	Systems.	fibrous.	fibrous. fibro-cartilaginous. dermoid.
6		muscular.	voluntary. involuntary.
7		erectile.	
8		mucous.	
9		serous.	
10		horny, or epidermous	pilous. epidermoid,
11		parenchymatous.	glandular.

These systems united together and with the fluids, compose the organs or the instruments of life. When many organs tend by their action to one common end, their assemblage is called an apparatus.

* *Traité de l'Anatomie Générale.*

† The French are wrong in attributing, as they always do, the originality of this classification to Pinel. The translator begs permission to quote a note on this subject from an inaugural dissertation published at Edinburgh, by his friend Dr. Elliotson in the year 1810. "Ad hunc modum primus de inflammatione scripsit CARMICHAEL SMYTH, M. D. in dissertatione pulcherrima, quam societati cuidam Londinensi, A. D. 1788, recitavit. *Medical Communications*, vol. ii. Decem post annis elapsis, eandem divisionem secutus est PINEL. *Nosographie Philosophique*, tom. i. BICHAT postea indicavit omnes morbos hac eadem ratione utilissime considerari potuisse. *Anatomie Generale*, passim. T.

Properties of Tissue.

The tissues which compose the organs possess physical and chemical properties, which it is important to study upon the dead body and the living subject. We find in them nearly all the physical properties which are observed in inert bodies, different degrees of consistence, from an extreme hardness to the consistence of a liquid, elasticity, transparency, refracting power, &c.; but certain properties have been particularly attended to, named *properties of tissue*. Such are extensibility and contractility of tissue, contractility *par racornissement*.

Independently of these physical properties, tissues have been studied in regard to their composition, and some have been found chiefly composed of gelatine, others of albumen, others of phosphate of lime, others of fibrine, &c.

These different tissues present also in the living animal certain phenomena which have not failed to attract the attention of physiologists.

A science is dedicated to describe tissues under the threefold relation of their physical, chemical, and vital properties: it is general anatomy, the study of which is of the highest importance to physiology.*

Of the fluids or humors.

The *fluids* of the bodies of animals, and particularly of man, bear a very considerable proportion to the solids: in an adult man, they are as 9 to 1. M. Professor Chaussier put into an oven, a body weighing 120lbs., which after several days became reduced to 12lbs. Bodies

* See Bichat's *Anatomie Générale.*

found after being long buried in the burning sands of the deserts of Arabia, have presented an extraordinary diminution of weight.

The animal *fluids* are sometimes contained in vessels, in which they move with more or less rapidity, sometimes in spaces or vacancies where they appear deposited, and at other times in great cavities, where they remain a longer or shorter period.

The fluids of the human body, which is the principal object of our study, are

1. The blood.
2. The lymph.
3. The *perspiratory fluids*, which comprehend the fluids of the cutaneous transpiration, and of that of the mucous, serous, and synovial membranes, of the cellular membrane, of the adipose cells, the medullary membranes, the interior of the thyroid, the thymus, &c.
4. The *follicular* fluids: the fatty fluid of the skin, the cerumen, the secretion of the Meibomian glands, the mucus of mucous glands and follicles, of the tonsils, the glands of the cardia, the neighbourhood of the anus, the prostate, &c.
5. The *glandular* fluids: the tears, saliva, pancreatic fluid, bile, urine, the fluid of Cowper's glands, semen, milk, the fluid of the suprarenal capsules, that of the testicles and breasts of new-born infants.
6. The chyme and chyle.

The physical and chemical properties of fluids are extremely various. Many are analogous in both these respects, but none completely resemble each other.

At all times much importance has been attached to classing them methodically, and according to the doctrine which flourished in the schools, particular classifications were established, founded upon it. Thus, the ancients who ascribed much importance to the four elements, said that there were four principal fluids, the blood, lymph or phlegm, yellow bile, and black bile or atrabilis: these four fluids corresponded with the four elements, the four seasons of the year, the four parts of the day, and the four temperaments.

At different times, other divisions have been substituted for this classification of the ancients. Thus three classes of fluids have been established: 1. chyme and chyle; 2. blood; 3. fluids produced from the blood. Some authors have been contented with two classes: 1. primary, alimentary or useless fluids; 2. secondary or useful fluids. Afterwards the fluids were divided into 1. *recrementitial*, i. e. fluids destined after their formation for the nourishment of the body; 2. *excrementitial*, or fluids to be removed from the economy; 3. fluids which have at once the characters of both classes, and are therefore called *excremento-recrementitial*. Lately chemists have attempted to class fluids according to their intimate nature; thus they have established albuminous fluids, fibrous, saponaceous, aqueous, &c.

The classification adopted by M. Professor Chaussier is much preferable; it regards neither the nature of fluids, nor their uses, &c.; but is founded upon the mode of their formation, which is the only invariable character which they present. We have followed this classification in the enumeration which has just been made of the fluids.*

* See the *Synoptical table of fluids*.

Causes of the phenomena peculiar to living bodies.

From the most ancient period it has been seen that a great part of the phenomena peculiar to living bodies do not follow the same course, are not subjected to the same laws as the phenomena peculiar to brute bodies.

The phenomena of living bodies have been ascribed to a particular cause. This has received different appellations: Hippocrates designated it φυσις (nature); Aristotle, *moving and generating principle*; Kaw Boërhaave, *impetum faciens*; van Helmont, *archea*; Staal, *soul*; others *vis insita, vis vitæ*, vital principle, &c. M. Chaussier, in his learned lectures, and in his *synoptical table of the characters of the vital powers*, adopts the name *vital powers*.

We must not abuse the meaning of this term *vital power*; it signifies, and can only signify, the *unknown cause* of the phenomena of life.

Just as attraction, say physiologists, presides over the changes of condition in inert bodies, does the vital power govern the modifications of organised bodies; but they fall into a strange error, for the vital force cannot be compared to attraction; the laws of the latter are perfectly known, those of the vital power are perfectly unknown. Physiology is, with respect to it, at this moment, exactly at the point at which the physical sciences were before the time of Newton: waiting for some genius of the first order, to discover the laws of the vital power, as Newton discovered those of attraction. The glory of this mathematician does not consist in having discovered attraction, as some believe, for this cause was already known; but in having said, that *attraction acts in the direct ratio of the mass, and the inverse ratio of the square of the distance.*

Vital Properties.

Physiologists, not contented with admitting the vital power, and making it of much importance in the explanation of the vital phenomena, have supposed that it manifested itself by vital properties, upon which some have founded not only physiology, but even pathology, and therapeutics.

These vital properties, which are generally admitted, have received different appellations: thus they have been called,

1. Organic, vegetative, nutritive, molecular sensibility.

2. Insensible organic, nutritive, fibrillary contractility, tone, tonicity.

3. Cerebral, animal, perceptive sensibility, sensibility of relation.

4. Sensible organic contractility, irritability, vermicular motion.

5. Voluntary, animal contractility, contractility of relation, &c.

Of these properties some are common to all living bodies, others peculiar to some parts of animals.

The first alone deserve the name of vital properties; but it is important to remark, that organic sensibility, and insensible organic contractility, are not obvious to the senses; they are evidently supposititious modes of conceiving and explaining the phenomena of life; they do not really exist, and yet no one at present doubts their existence. We speak of the alterations which they experience, and of the necessity of bringing them back to their usual state: even medicines have been classed according to their mode of acting upon these principles, and many physicians treat their patients according to this doctrine.

This fundamental principle of physiology and medicine is evidently wrong.

The other properties are peculiar to some animals, and even only to some of their parts: such is sensible organic contractility, seen in the heart, intestines, bladder, &c. but which is not observed in other parts of the economy.

Cerebral, or, as Bichat called it, animal sensibility, as well as voluntary contractility, have been included in the number of vital properties only by an abuse of words: it is clear that they are functions or results of the action of many organs, which in their action have a common end.

We say nothing of the *power of vital resistance, of fixed situation, vital affinity, caloricity*, because these different properties, although proposed by men of great merit, have not obtained general assent, and because we see no necessity to admit them. Our opinion of the vital properties therefore lead us to reject insensible organic contractility and organic sensibility, as useless and dangerous suppositions; to consider sensible organic contractility as an organic action, and voluntary contractility and cerebral sensibility, as functions.

The doctrine of vital properties has not been applied to the fluids, and nevertheless they are regarded as alive. But more wisdom has been shewn in regard to the fluids than the solids, for their endowment with vitality has been established on the sensible phenomena only which they offer. Thus the fluidity which they preserve as long as they constitute a part of the body of the animal; the mode in which some become organised when removed from the vessels; the faculty of producing heat, &c. are the principal phenomena, which, according to modern physiologists, denote that the fluids are alive. We must add, that all animal fluids have not these-characters. Blood, chyle, lymph, and some other fluids destined for nutrition, alone present them. Excrementitial fluids, such as bile, urine, the cutaneous fluid or transpiration, &c. offer nothing analogous: all therefore which is said of the life of the fluids must not be understood of the latter. Previously to commencing the study of the phenomena of the life of man, the particular object of this work, we must make one general remark.

Whatever may be the number or diversity of the phenomena of the living man, it is easily seen that they may be ultimately reduced to two principal ones; *nutrition* and *vital action*. A few words upon each of these phenomena are indispensable for comprehending what will follow.

The life of man and other organised bodies is founded upon their habitually assimilating a certain quantity of matter called *aliment*. The privation of this matter for a very limited period necessarily causes the cessation of life. On the other hand, daily observation shows that the organs of man and other living beings, lose every moment a certain quantity of the matter which composes them; and it is in fact from the necessity of repairing these habitual losses, that the necessity for nourishment arises. From these two data, and some others which we shall make known in our progress, it has been concluded with reason, that living bodies are not composed of the same matter at every period of their existence: it has been even said that bodies undergo a total renovation. The ancients maintained that this renovation takes place every seven years. Without admitting this conjecture, we shall say that it is extremely probable that every part of the human body experiences an intestine movement, the object of which is both to expel the particles which are no longer destined to remain in the composition of the organs, and to replace them by fresh particles. This intimate movement constitutes nutrition. It is not sensible, but its effects are, and to doubt its occurrence would be the height of scepticism. This movement is inexplicable, and can be referred, in the present state of physiology, only to the molecular movements of chemical affinity. To say that it depends on organic sensibility and insensible organic contractility, or simply on vital force, is merely expressing the same fact in different terms. However this may be, the organs of the human body preserve and change their physical properties in virtue of their nutritive movement, or of nutrition. As our different organs present different physical properties, the nutritive movement must vary in each of them. Independently of the physical properties which every part of the body presents, there are many which offer either continually, or at more or less distant intervals, a phenomenon termed *vital action*. For example, the liver continually forms a fluid called *bile*, in virtue of a power peculiar to it; the same may be said of the kidney with respect to the urine. The voluntary muscles, under certain conditions, harden and change their form; in a word, contract. This also is an instance of a vital action. These vital actions are very important to the life of man and animals, and particularly demand the attention of the physiologist.

Vital action depends evidently upon nutrition, and nutrition again is influenced by vital action. Thus an organ which ceases to be nourished, loses at the same time the faculty of acting; thus organs whose action is the most frequently repeated, have a more active nutrition: on the contrary, those which act less, have evidently a sluggish nutritive movement.

The mechanism of vital action is unknown. There occurs in the organ which acts an insensible molecular movement, as inexplicable as the nutritive movement. No vital action, however simple, is an exception in this respect.

All the phenomena of life may be thus ultimately referred to nutrition and vital action; but the molecular movements which constitute these two phenomena are not sensible, and we must not direct our attention to them; we can study their last results only, i. e. the physical properties of organs, and the sensible effects of the vital actions, and examine how they both concur to general life.

This in fact is the object of physiology.

To arrive at this end, the phenomena of life are divided into different classes or functions.

Authors have varied much in their classification of the functions. Without stopping to enumerate, as would not be proper in a work of this kind, the various classifications which have been adopted at different periods, we shall say, that the functions may be divided into those which are destined to place the individual in relation with surrounding objects; those whose object is nutrition; and those which are intended for the reproduction of the species.

We shall call the first, *functions of relation*; the second, *nutritive functions*; and the third, *generative functions*.*

The mode of studying a particular function, is not a

* For the display of the different systems of classification, consult M. Richeraud's *Physiologie*, and M. Chaussier's *Table des Functions*. In our private lectures, we give details on this subject.

matter of indifference. The following is that which we adopt.

1. The general idea of the function.

2. The circumstances which put the organs into action, and which we shall denominate, *excitants of the function.*

3. The summary anatomical description of the organs which contribute to the function, or of the apparatus.

4. The study of the action of each organ in particular.

5. General recapitulation, showing the utility of the function.

6. The relation of the function with those previously examined.

7. The modifications of the functions according to age, sex, temperament, climate, seasons and habit.

OF THE FUNCTIONS OF RELATION.

The functions of relation consist of the *sensations,* the *mind,* the *voice,* and *motions.*

OF THE SENSATIONS.

The sensations are functions destined to receive impressions from external objects, and transmit them to the mind. These are five in number: *vision, hearing, smell, taste,* and *touch.*

OF VISION.

Vision is the function by which we learn the size, figure, colour, and distance of bodies, &c.

The organs which compose the apparatus of vision enter into action by the influence of a particular excitant called *light.*

We perceive bodies and may learn many of their properties, although they are often very distant from us; there must consequently be some intermediate agent between them and our eye; this agent is named *light*.

Light is an extremely subtle fluid, emanating from bodies called *luminous*, such as the sun, the fixed stars, ignited and phosphorescent bodies, &c.

Light is composed of particles moving with prodigious rapidity, for each passes through about eighty thousand leagues in a second.

A ray of light is a series of particles succeeding each other in a straight line without interruption. The particles which compose each ray are separated by considerable intervals, compared with their masses; hence a very great number of rays may cross each other at the same point, without striking against one another.

Light emanating from luminous bodies forms diverging cones, which, if they met with no obstruction, would be prolonged indefinitely.

Philosophers have hence concluded that the intensity of light in any place, is in the inverse ratio of the square of the distance of the luminous body from which it emanates. The cones formed by light emanating from luminous bodies, are in general named *bundles of light*, and the *bodies* in which the light moves are called *media*.

When light meets in its progress with certain bodies termed *opake*, it is repelled, and its direction modified according to the disposition of these bodies.

The change which the course of light experiences in this case is called *reflection*. The study of reflection constitutes that part of physics which is called *catoptrics*.

Certain bodies, as glass, allow light to pass through them: they are termed *transparent* or *diaphanous*. Light in passing through them undergoes a certain change called *refraction*. As the mechanism of vision rests entirely upon the principles of refraction, it is necessary to spend a few moments in their examination.

The point at which a ray of light enters into a medium is called the point of *immersion*, and that at which it comes out, the point of *emergence*.

If the ray strikes perpendicularly on the surface of a medium, it continues its course through the medium, in its original direction; but if it strikes obliquely on the surface of the medium, it deviates from its course and appears broken at the point of immersion.

The angle of incidence is that which is made by the incident ray with a perpendicular line drawn through the point of immersion on the surface of the medium, and *the angle of refraction* is that which is made by the broken ray with the same perpendicular.

If the ray of light passes from a rarer into a denser medium, it approaches the perpendicular at the point of contact; it separates from it, on the contrary, when it passes from a denser into a rarer medium. The same phœnomenon occurs, but in an opposite manner, when the ray again enters into the first medium; so that if the two surfaces of the medium which the ray traverses are parallel, the ray on returning into the surrounding medium will take a direction parallel to the incident ray.

Bodies refract light in proportion to their density,* and

* Density is the relation of mass to volume, so that if all bodies were of the same volume, their densities might be measured by their weight.

their combustibility. Thus if the two bodies are of equal density, but the one composed of elements more combustible than the other, the refracting power of the first will be greater than that of the second.

All diaphanous bodies, when they refract light, also reflect it. In consequence of this property, these bodies, to a certain degree, fulfil the office of mirrors. If they have little density, as the air, they are not visible unless their mass is considerable.

The form of the refracting body does not influence its refracting power, but modifies the disposition of the refracted rays with respect to each other. In fact, as perpendiculars to the surface of a body approach and recede according to its form, the refracted rays must at the same time approach and recede from each other.

When, from the effect of a refracting power, rays tend to approach each other, the point at which they unite is called the *focus of the refracting power.*

Bodies of a lenticular* form chiefly present this phænomenon.

A refracting body with parallel surfaces does not change the direction of the rays, but approximates them to its axis by a sort of transport. A refracting body, convex on each side (a lens) has not a greater refracting power than a body convex on one side and plane on the other; but the point at which the rays meet behind it is nearer.

The study of refraction leads us to notice an extremely important fact, viz. *that a ray* of light is itself composed of an infinity of rays of different colours and different

* Lenticular bodies are bodies bounded by two segments of spheres.

degrees of refrangibility, *i. e.* although the medium and the angle of incidence be the same, the refraction of each coloured ray varies with its colour.

If a bundle of luminous rays is made to pass through a glass prism or any other refracting body whose surfaces are not parallel, the bundle enlarges, and if, after its departure from the body, it is received upon a plain, as a sheet of paper, it is found to occupy a large extent, and instead of producing a white image, it produces one oblong and of innumerable colours, succeeding each other by insensible degrees, and among which the seven following colours are distinguishable; red, orange, yellow, green, blue, indigo, and violet. Each of these colours is indecomposable; their assemblage forms the *solar spectrum.* Thus light is not homogeneous, since it is composed of very differently coloured rays. Upon this fact is founded the explanation of the colours of bodies. A white body is one which reflects light without decomposing it; a black body, one which does not reflect, but completely absorbs it. Coloured bodies decompose light, while reflecting it: they absorb part and reflect part. Thus a body will appear green, when the union of the colours which it reflects, forms green, &c.

Transparent bodies also appear coloured by the light which they refract, and when seen by refraction, they often appear of a different colour than when seen by reflection.

If it is inquired why such a body reflects a certain colour, while another absorbs it? philosophers answer, that this phænomenon depends upon the nature and particular disposition of the particles of bodies.*

The discovery of the action of refracting bodies upon

* This explanation very much resembles that of the phænomena of life, by the vital properties, *i. e.* it explains nothing.

light has not been an object of mere curiosity, but has led to the construction of ingenious instruments, by means of which the sphere of human vision is remarkably extended.

Apparatus of Vision.

The apparatus of vision is composed of three distinct parts.

The first modifies light.

The second receives its impression.

The third transmits this impression to the brain.

The texture of the apparatus of vision is so extremely delicate, that it is affected by the slightest cause; nature has therefore placed before it a series of organs to protect and preserve it in the conditions requisite for the free exercise of its functions.

These protecting parts are the eye-brows, eye-lids, and the secretory and excretory organs of the tears.

The eye-brows, peculiar to man, are formed, as is well known,

1. Of hairs of varying colours.
2. Of skin.
3. Of sebaceous follicles arranged at the base of each hair.
4. Of muscles destined for their various movements, viz. the frontal portion of the occipito-frontalis, the superior edge of the orbicularis palpebrarum, and the corrugator supercilii.
5. Of numerous vessels.
6. Of nerves.

The eye-brows have many uses. The projection which they form, protects the eye from external violence; the hairs, from their oblique direction, and the oily matter which covers them, prevent the sweat from running towards the eye and irritating the surface of this organ, and direct it towards the temple and root of the nose. The colour and number of the hairs of the eye-brows influence their use. They usually vary with climate. In the natives of hot climates they are very thick and black; in those of cold climates, they may be thick, but are very seldom black. The eye-brows protect the eye from the impression of too strong a light, more especially when coming from above: we increase this effect by frowning.

There are two eye-lids in the human subject, distinguished into superior and inferior, and great and small, *palpebra major, palpebra minor.*

The form of the eye-lids is accommodated to that of the globe of the eye, so that when approximated, they completely cover its anterior surface. Their line of meeting is not parallel with the transverse diameter of the eye, but much below it; hence Haller improperly terms it *æquator oculi.*

The more extensive the interval between the eye-lids, the larger does the eye appear; our opinion, therefore, respecting the size of the eye is often incorrect; and most frequently relates to the extent of the opening of the eye-lids.*

The free edge of the eye-lids is resisting and furnished with hairs more or less long and numerous, usually of the same colour as those of the head, and arranged very near each other. Those of the upper eye-lids form a slight curve concave above; those of the lower eye-lid a curve concave below. We attach an idea of beauty to numerous and long eye-lashes, which corresponds with the

* Bichat.

advantage resulting from them. The eye-lashes are always covered with an unctuous fluid afforded by little follicles situated in the substance of the eye-lids, at the base of the eye-lashes. This is common to them and most of the hairs.

Between the line occupied by the eye-lashes and the internal surface, is a flat surface by which the eye-lids touch when they meet. I call this the *margin* of the eye-lids.

The eye-lids are composed of a muscle with semicircular fibres *(orbicularis palpebrarum)*, of a fibro-cartilage, of a ligament *(broad ligament of the eye-lids)*, of a large number of sebaceous follicles *(glands of Meibomius)*, and of a portion of mucous membrane.

The skin of the eye-lids is very delicate and semi-transparent, yielding readily to their motions, and presenting transverse folds. The muscle of the eye-lids, by its contraction, approximates them, or, as we say, shuts the eye, and at the same time carries the eye-lids a little inwards.

The fibro-cartilage of the eye-lids is named tarsal cartilage; that of the upper eye-lid is much larger than that of the lower. Their use is to preserve the eye-lids extended, and always accommodated to the form of the eye; they, besides this, support the eye-lashes, contain the follicles of Meibomius in their substance, and defend the eye from external injuries. The use of the cartilage in regard to the movements of the eye-lids does not appear indispensable, since it is not found in many animals, whose eye-lids perform their functions equally well with ours.

The *broad ligament* is nothing more than the cellular membrane which runs from the bottom of the orbit, to the superior edge of the tarsal cartilage; it appears intended to limit the movement which approximates the eye-lids to each other.

The cellular tissue of the eye-lids is extremely fine and delicate, and contains no fat, but a very thin serosity, which in certain cases acquires more consistency, and accummulates in the cells; the eye-lids then become tumid and blue. These effects are observable after every kind of excess, after violent diseases, and during convalescence, in women when menstruating, &c.

Fineness, and laxity of the cellular membrane of the eye-lids, and the absence of fat, were indispensable to the free exercise of their movements.

The ocular surface of the eye-lids is covered by a mucous membrane.

Besides the parts just described, the upper eye-lid has a muscle peculiar to itself, called *elevator palpebræ superioris.*

The eye-lids cover the eye during sleep, and preserve it from the contact of foreign bodies flying in the atmosphere; guard it from blows by shutting almost instantaneously; by their habitual motions, which occur after nearly equal intervals, they oppose the effects of the prolonged contact of the air; they also moderate the force of too strong a light, for by approximating they allow such a quantity of this fluid to pass as is necessary to vision, but incapable of injuring the eye. On the contrary, when the light is weak, we open the eye-lids widely, to allow as much as possible to enter the eye.

When the eye-lids are brought near each other, the eye-lashes form a sort of grating, which permits a certain quantity only of light to pass at once.

When the eye-lashes are wet, the little drops on their surface decompose light as the prism does, and the point from which it emanates appears irradiated. The eye-lids, by separating into bundles the light which penetrates the eye, cause bodies on fire, during the night, to appear surrounded with luminous rays. This effect disappears the moment the lids are opened, or merely another direction given to the eye-lashes. We may readily conceive that the eye-lids protect the eye from the particles of dust which fly in the air. Vision is always more or less altered in persons deprived of their eye-lashes.

The *glands of Meibomius* are compound follicles lodged in the substance of the tarsal cartilages. They are very numerous; from thirty to six-and-thirty in the upper eye-lid, and from four-and-twenty to thirty in the lower. In each compound follicle is a central canal, around which are placed the simple follicles, and into which they pour the matter which they secrete. This central canal is always filled with this matter, which in its ordinary state is called *fluid of Meibomius*, and *gum* when thickened and dry. At the moment of waking, a certain quantity is always found accumulated in the great angle of the eye, and on the edge of the eyelids. It is commonly considered unctuous, but particular investigation has convinced me, that it is really albuminous. Each central canal has an opening scarcely indeed visible, on the internal surface of the eyelid, very near its junction with the margin. These openings, placed very near each other, extend through the whole length of the edge of this margin. The fluid of Meibomius escapes through these openings, when the lid is slightly compressed. As these suffer a sensible degree of pressure when carried before the eye, it is probable that this pressure contributes to the excretion of the fluid. The principal use of this fluid, I conceive, is to favour the friction of the eye-lids upon the globe of the eye. As the upper eyelid rubs the most against the eye, it ought to have larger and more numerous follicles; and this is actually the case.

Lachrymal Apparatus.

The eyebrows and lids are not the only parts destined to protect the eye, and preserve it in the condition necessary for vision: among the *tutamina oculi* is a little secretory apparatus, of very curious mechanism and great utility. It is the secreting apparatus of the tears. It consists of the lachrymal gland and its excretory canals, the lachrymal caruncle, the lachrymal ducts, and the nasal canal.

Lodged in a little depression, situated at the upper and outer part of the vault of the orbit, the lachrymal gland is of small size It secretes the tears.

This gland, but not its office, was known to the ancients, and called by them *innominata superior*, in opposition to the caruncle, which they termed *innominata inferior.* Some ascribed the formation of tears to the caruncle, others to a gland which has no existence in the human subject, but in certain animals *(the gland of* Harderus).

There are six or seven excretory canals of the tears. They arise from little glandular grains, which by their assemblage form the gland; they run some way in the intervals of the lobules, but soon leave the gland, and lie upon the conjunctiva, which they penetrate near the tarsal cartilage of the upper eyelid, towards its outer extremity. They may be rendered visible, by inflation, by raising the upper eye-lid and compressing the gland, which causes the tears to flow through the orifices of those canals, by macerating the eye in water tinged with blood, or finally by injecting them with mercury. Through these ducts, the tears are discharged on the surface of the conjunctiva.

At the internal angle of the eye, we observe a projecting body, the florid colour of which indicates general energy, and the paleness of which on the contrary, indicates a state of debility and disease: it is the lachrymal caruncle. This small body is composed of seven or eight follicles, ranged in a semicircular line, convex inwards. Each has an opening on the surface of the caruncle, and contains a little hair; these openings are so disposed, that with the glands of Meibomius, they complete a circle which embraces all the anterior part of the eye when it is open.

At the spot where the eye-lids quit the globe to run towards the caruncle, on the internal surface, near the free edge, each lid has a little opening; this is the lachrymal punctum, the external orifice of the lachrymal ducts. These puncta are continually open, and both directed towards the eye. They are supposed to be endowed with a contractile power, which manifests itself when they are touched with a stylet. Whatever care I have taken to discover these contractions, I have never succeeded: there is a circumstance which may have caused some deception. When the attempts at introducing a stylet have been in vain repeated, the mucous membrane which lines the puncta swells from the afflux of fluids, as it would do in any other part, and then the opening is really narrowed: this phenomenon must of course be distinguished from contraction.

By means of the lachrymal ducts, the openings of which we have just spoken lead to a canal running from the great angle of the eye to the lower part of the nasal fossæ. The lachrymal canals are very narrow, they scarcely permit the passage of a hog's bristle, and are three or four lines in length; they are placed in the substance of the eye-lid, between the orbicularis muscle and the conjunctiva. They open sometimes separately, sometimes together, into the upper part of the nasal canal.

Anatomists are wrong to divide into two parts the duct which extends from the great angle of the eye to the inferior meatus of the nasal fossæ. This canal has throughout its length nearly the same dimensions, and nothing can justify the appellation of *lachrymal sac*, which is given to its upper part, while that of *nasal canal* is reserved for the remainder of its length. However, this canal is formed by the mucous membrane of the nasal fossæ which is extended into the bony canal existing along the posterior edge of the erect process of the maxillary bone, and the anterior half of the os anguis. Its use is to convey the tears into the nasal fossæ.

Among the organs of the lachrymal apparatus, we ought to enumerate the conjunctiva, a mucous membrane, which covers the posterior surface of the eye-lids and the anterior part of the globe of the eye. This membrane is larger than the part which it runs along, a circumstance extremely favourable to the motions of the eye and eye-lids. The loose manner in which it adheres to the eye-lids, and the sclerotic, accommodates it still more to these movements. Does the conjunctiva pass before the transparent cornea, or stop at the circumference of this part of the eye, to be continued into the membrane which invests it? This is not completely demonstrated. The general opinion is, that it covers the cornea; but M. Ribes, a very distinguished anatomist, believes that the cornea is covered by a peculiar membrane, united at its circumference to the conjunctiva, without being a continuation of it.

The conjunctiva protects the anterior surface of the eye, secretes a fluid which mixes with the tears and appears to have the same office, possesses the power of absorption,* supports the friction which occurs when the eye moves, and, being very polished and constantly moist, renders these motions very easy. Lastly, it receives the contact of the air when the eye is not covered by the bed of tears, of which we are going to speak.

Of the Secretion and Use of the Tears.

We are not at present to describe the secretion of the tears, to shew in what it resembles, and in what it differs from the rest of the secretions: it is sufficient to know that the lachrymal gland forms, and by means of the ducts of which we have spoken, pours them upon the conjunctiva, at the outer and upper part of the eye. But what becomes of them when arrived at this part? That we shall now explain. We observe, in the first place, that they must flow in a different manner when we are asleep than when we are awake. When we are awake, the eye-lids are alternately approaching and separating from each other; the conjunctiva is exposed to the contact of the air; the eye is in continual motion; nothing of this kind occurs during sleep.

* One may poison an animal by applying poisonous substances to the conjunctiva. Hence we do not agree with Mr. Adams, a celebrated London oculist, that the extract of Belladonna may be long applied to the eye without inconvenience.

Physiologists suppose that the tears flow in a triangular canal, destined to conduct them towards the great angle of the eye, where they are absorbed by the puncta lachrymalia. This canal, they say, is formed, 1. by the edge of the eye-lids, whose surfaces, rounded and convex, touch only at one point; 2. by the anterior surface of the eye, which completes it behind. The external extremity of this canal is more elevated than the internal. This disposition, joined with the contraction of the orbicularis muscle, whose point is fixed to the nasal process of the superior maxillary bone, directs the tears towards the puncta lachrymalia.

This explanation is defective: the eye-lids are in contact, not by a rounded edge, but by their margins, which are flat; the canal therefore of which they talk does not exist. In fact, if we examine the posterior surface of the eye-lids when in contact, we can scarcely detect the line which indicates the point at which they touch. Besides, if we admit the existence of this canal, it can serve for the passage of the tears during sleep only; we should still have to inquire into their course during the waking state.

During sleep, and whenever the eye-lids meet, the tears gradually diffuse themselves over all the ocular and palpebral surface of the conjunctiva, and must stream in the largest quantity where they find the least resistance. The course which presents the fewest obstacles, is along the part where the conjunctiva passes from the eye to the eye-lids; along this they easily arrive at the puncta lachrymalia. The tears thus diffused upon the conjunctiva must mix with the fluids secreted by this membrane, and experience the absorption which it carries on.

When we are awake, things go on differently. The portion of the conjunctiva in contact with the air, allows the tears which are upon it to evaporate, and would become dry if the tears were not renewed by the motion of winking, of which I conceive this to be the chief purpose. The tears thus lying on the part of the conjunctiva exposed to the air, form upon it an uniform layer, which gives to the eye its polish and brilliancy; the increased or diminished thickness of this layer greatly influences the expression of the eyes; in empassioned looks, for instance, it is obviously thicker.

In the ordinary condition of the lachrymal secretion, the tears are not in the least disposed to overflow the lower eye-lid. I know not upon what can be founded the use commonly ascribed to the fluid of Meibomius, of opposing this overflow, somewhat as a layer of oil upon the edge of a vessel opposes a watery fluid which rises above it. This effect of the Meibomian secretion I doubt, because it is soluble in the tears. The tears which do not evaporate, or are not absorbed by the conjunctiva, are absorbed by the lachrymal ducts, and carried to the inferior meatus of the nostrils by the nasal canal. How this takes place is unknown. Explanations have been given, founded on the theory of the syphon, capillary tubes, vital properties, &c., but are uncertain.* The absorption of the tears by the lachrymal puncta, is evident only when the tears are very abundant or streaming in the eyes.

Apparatus of Vision.

The apparatus of vision is composed of the eye and optic nerve.

* The explanation by absorption, arising from the capillary nature of the lachrymal ducts, unites the greatest number of probabilities.

The position of the eye at the most elevated part of the body; the power of perceiving an object with both eyes at once; the oblique direction of the base of the orbit; the presence of a great abundance of fatty cellular substance which forms an elastic cushion at the bottom of the orbit, are circumstances worthy of remark, but which we can only hint at.

The eye consists of parts of very different offices in the function of vision. They may be distinguished into those which refract, and those which do not.

The refracting parts are

A. The transparent cornea, a refracting body, convex and concave, resembling very much in its figure, transparency, and mode of insertion, the glass placed before the face of a watch.

B. The aqueous humour, filling the chambers of the eye; it is not purely aqueous, as its name implies, but is composed of water and a little albumen.*

C. The crystalline, improperly compared to a lens. The comparison is exact as far as regards form; but with respect to structure, is completely defective; for the crystalline consists of concentric layers, gradually increasing in hardness from the surface to the centre, and probably of different refracting powers. The crystalline is, besides, enveloped in a membrane, which experience proves to be of great importance in vision. A lens is homogeneous throughout, at its surface and every point of its substance, and has also throughout the same power of refraction. We must, however, remark, that the curve of the anterior part of the crystalline is far from resem-

* According to Berzelius, the aqueous humour is composed of water, 98,10; albumen, a little; muriates and lactates, 1,15; soda, with a matter soluble in water only, 0,75; altogether, 100,0.

bling that of the posterior. The latter belongs to a sphere of much smaller diameter than the sphere to which the posterior curve belongs. Hitherto the crystalline has been supposed to consist in a great measure of albumen; according to the recent analysis of Berzelius, it contains none, but is formed almost entirely of water and a peculiar matter very analogous in its chemical properties to the colouring matter of the blood.

D. Behind the crystalline is the vitreous humour, so called from its resemblance to melted glass.* Each of the parts just mentioned is enveloped in a very fine membrane, as transparent as itself: thus, before the cornea is the conjunctiva, and behind it the *membrane of the aqueous humour*, which lines all the anterior chamber of the eye, i. e. the anterior surface of the iris and the posterior of the cornea. The crystalline is surrounded by the *crystalline capsule*, the circumference of which adheres to the membrane which covers the vitreous humour. In passing from the circumference of the crystalline to the anterior and posterior surfaces, it leaves between its laminæ a space called *canal goudronné*. Hitherto no communication has been supposed to exist between this canal and the chamber of the eye; but M. Jacobson maintains that there is a number of small openings, by which the aqueous may pass in and out of this canal. We have in vain looked for them.

The vitreous humour also is surrounded by a membrane termed *hyaloïd*. This membrane not only contains the vitreous humour, but plunges into it, and divides it into a number of cells. The examination of these cells adds

* According to Berzelius, the vitreous humour contains water, 98,40; albumen, 0,16; muriates and lactates, 1,42; soda and a matter soluble in water only, 0,02; total, 100,0.

nothing to our knowledge of the use of the vitreous humour.

The eye is composed not only of parts which refract, but also of membranes, each of which has some particular use. They are

A. The sclerotic, the external coat of the eye, fibrous, thick and resisting, and evidently intended to protect the interior of the organ; it serves also for the insertion of the muscles which move the eye.

B. The choroid, a vascular and nervous membrane, formed of two distinct laminæ, and impregnated with a black matter which is of much importance in vision.

C. The iris, found behind the transparent cornea, of different colours in different persons, and pierced in the centre by an opening called *pupil*, which increases and decreases according to circumstances which we shall mention. The iris adheres, anteriorly and at its circumference, to the sclerotic, by a cellular substance of a peculiar nature, and termed *ciliary* or *iridian ligament*. The posterior surface of the iris is covered with an abundance of black matter.

Behind the circumference of the iris is observed a large number of white lines, disposed like rays, which would meet in the centre of the iris if prolonged; they are the *ciliary processes*. Neither their structure nor their use is ascertained: some imagine them nervous, others muscular, others glandular or vascular. In fact, we are acquainted neither with their true structure nor their uses, as we shall presently see. The colour of the iris depends upon that of its substance, which is variable, and upon that of the black layer upon its posterior surface, the colour of which penetrates through the iris. In blue eyes, for example, the substance of the iris is nearly white; the posterior black layer appears nearly alone, and determines the colour of the eyes.

Anatomists are not agreed respecting the structure of the iris; some consider it similar to the choroid, i. e. essentially composed of vessels and nerves; others think they can discover muscular fibres in it; some regard it as a structure *sui generis;* others again class it with the erectile structures. M. Edwards has lately demonstrated that the iris consists of four layers, easily distinguished, two of which are continuations of the laminæ of the choroid; a third belongs to the membrane of the aqueous humour; and a fourth constitutes the proper substance of the iris.

Between the choroid and hyaloïd is a membrane completely nervous, known by the name of *retina,* and nearly transparent, slightly opake, and faintly tinged of a lilac hue, and formed by the expansion of the filaments of the optic nerve. M. Ribes regards it in a different point of view; he believes it to be a peculiar membrane, in which the branches of the optic nerve are distributed, and thus establishes an analogy between the retina and other membranes. At the distance of two lines from the optic nerve, towards the temple, is a yellow spot, and near it, one or more folds. These appearances are observable in man and some of the simiæ only.

The eye receives a great number of vessels (*ciliary arteries and veins*), and several nerves, most of which proceed from the ophthalmic ganglion.

Optic Nerve.

This nerve is the medium of communication between the eye and the brain. It does not arise from the optic thalamus, as most anatomists imagine, but, 1. From the anterior pair of the tubercula quadragemina; 2. From the *corpus geniculatum externum*, an eminence found before and a little to the outer side of these tubercles ; 3. and lastly, from the layer of grey substance which is placed between the meeting of the optic nerves and mammillary eminences, and known under the name of *tuber cinereum*. The two optic nerves approach each other, and appear blended together on the upper surface of the body of the sphenoid bone.

Much pains has been taken to ascertain whether they decussate, are merely in contact, or really blended together. Anatomy has not yet determined this question. Pathology furnishes proofs in favour of each of these opinions ; thus when the right eye has long been wasted, the whole length of the optic nerve on the same side has been likewise found wasted. In other cases, where the right eye was wasted, the anterior portion of the nerve of the same side has been evidently wasted, and also the posterior portion of the left. Some have thought that the decussation of the optic nerves of fish removed all doubt upon the subject, but this fact furnishes at best only probability.

The optic nerve is not formed of a fibrous envelope and a central pulp, as the ancients believed, but is composed of very fine filaments, parallel to each other, and communicating together as other nerves do. This disposition is very evident in that portion of the nerve which extends from the cella turcica to the eye.

Mechanism of Vision.

To facilitate the exposition of the progress of light in the eye, let us suppose a single luminous cone proceeding from a point placed in the prolongation of the antero-posterior axis of the eye. It is clear that the light which falls on the cornea only can serve for vision; what falls upon the white of the eye, the eye-lashes and eye-lids, cannot contribute to it, but is reflected differently from these parts according to their colour. The whole extent of the cornea itself does not receive light, for it is usually covered above and below by the free edge of the eyelids.

As the surface of the cornea is highly polished, the moment the light reaches it, a part is reflected, contributing to form the brilliancy of the eyes. It is this same light which forms the images perceived behind the cornea. In this case, the cornea fulfils the office of a convex mirror.

The form of the cornea indicates the influence it must have upon the light which enters into the eye; in proportion to its thinness, it simply causes the rays of light to approach a little to the axis of the bundle; in other terms, it *increases the intensity* of the light which reaches the anterior chamber.

Uses of the Aqueous Humour.

While passing through the cornea, the rays have passed from a rarer to a denser medium; consequently they must have approached the perpendicular at the point of contact; if on entering the anterior chamber they passed into the air, they would incline from the perpendicular as much as they had approached it, and would therefore regain their former divergency; but in the aqueous humour they enter a medium more refracting than air; they deviate less from the perpendicular, and consequently diverge less than if they had again passed into the air. Of all the light which has entered the anterior chamber, that portion only which passes through the pupil serves for vision; what falls upon the iris is reflected, passes again through the cornea, and displays the colour of the iris without.

While passing through the posterior chamber, the light experiences no further modification, as it is merely passing through the same medium (the *aqueous humour*.)

Uses of the Crystalline.

The light undergoes the most important modification during its passage through the crystalline. Philosophers compare the action of this body to that of a lens intended to collect upon the retina all the rays of any cone of light. But as the crystalline is far from being a lens, we shall only mention this generally received opinion, remarking that further investigation of the subject is required. All that we know for certain is, that the crystalline must augment the intensity of the light directed to the bottom of the eye, with greater force in proportion to the greater convexity of its posterior surface. We may add that the light which passes from the circumference of the crystalline is probably refracted in a different manner from that which passes through the centre,* and that consequently the enlargement and diminution of the pupil must exert upon vision an influence which deserves the attention of philosophers.

The light which has struck the anterior surface of the crystalline does not all penetrate the vitreous humour, but is in part reflected. On the one hand, this reflected light passes back again through the aqueous humour and cornea, and contributes to produce the splendour of the eye, and on the other falls upon the posterior surface of

* The structure of the crystalline may correct the aberration of sphericity which ordinary lenses produce.

the iris, where it is absorbed by the black matter which exists there.

It is probable that something of this kind occurs in each lamina of the crystalline.

Uses of the Vitreous Body.

The *vitreous* body has a less refracting force than the crystalline, and consequently the rays of light penetrating it after passing through the crystalline, incline from the perpendicular at the point of contact.

Its use in regard to the course of the rays in the eye, is therefore to increase their convergency. One might say that nature, to produce the same effect, had only to give the crystalline a little more refracting power; but the presence of the vitreous humour answers another much more important purpose, that of giving the retina a greater extent, and thus augmenting the field of vision.

What we said respecting a cone of light proceeding from a point placed in the prolongation of the antero-posterior axis of the eye, must be repeated in regard to every luminous cone proceeding from all other points and directed towards the eye; with this difference, however, that in the first case, the light tends to unite in the centre of the retina, whilst the light of other cones would tend to unite in different parts according to its point of emanation.

Thus the luminous cones proceeding from below, will unite at the upper part of the retina, those from above, at the lower part. The other rays follow a similar course, so that at the bottom of the eye will be formed an exact representation of each of the bodies placed before it, with this difference, that the images will be placed inversely with respect to the objects which they represent.

Different means are used to ascertain this fact. Artificial eyes have been long employed, having the cornea and crystalline represented by glass, and the aqueous and vitreous humour by water. Another mode was generally adopted before the publication of my memoir upon the *images which are formed at the bottom of the eye*. It consists in placing the eye of an animal (an ox, sheep, &c.) in the window shutter of a darkened room, having previously removed the posterior part of the sclerotica. The images of objects placed so as to send rays towards the pupil are there seen very distinctly upon the retina.

I employ a more easy method. I take the eyes of a rabbit, pigeon, puppy, owl, duck, in which the choroid and sclerotic are nearly transparent: I accurately remove the fat and muscles from their posterior part, and on directing the transparent cornea towards luminous objects, I very distinctly see the images of them upon the retina.

The method just described was known to Malpighi and Haller. I have one of my own which consists in using the eyes of albino animals, as of white rabbits, albino pigeons, white mice (those of albino human subjects would probably be well adapted for this experiment). These eyes are very favourable for the result of this experiment: the sclerotic is fine, and very nearly transparent: the choroid is equally fine: as the blood which coloured it during life disappears after death, it is rendered incapable of opposing any sensible obstacle to the passage of light.

The facility and accuracy with which images are perceived by this method, suggested to me the idea of making some experiments which might confirm or weaken the received theory of the mechanism of vision.

If a small opening is made in the transparent cornea, and a small quantity of the aqueous humour allowed to escape, the image has not the same accuracy; and the same effect follows the escape of a certain quantity of the vitreous humour through the sclerotic: facts which prove that the proportion of the aqueous and vitreous humours have a relation with the perfection of vision.

I have endeavoured to determine the law of the dimensions of the image relatively to the distance of the object, and have found the size of the image evidently proportional to the distance.

M. Biot has had the goodness to join me in verifying this result, which is moreover conformable to that which Le Cat has given in his *Treatise on the Sensations.* This author employed artificial eyes in his researches.

I made a small opening in the circumference of the transparent cornea, near its junction with the sclerotic, and forced out all the aqueous humour: the image (that of the flame of a taper) appeared, other things being equal, to occupy a larger space upon the retina, and was also less neat, and formed of light less intense than the image of the same body seen in the eye of another animal, placed in the same relation to the taper, but remaining uninjured that I might compare them,—a result conformable to what we said respecting the use of the aqueous humour in vision.

It is the same with the cornea; if it is entirely removed by a circular incision made at its junction with the sclerotic, the dimensions of the image are unchanged, but the light of which it consists, sensibly loses its intensity.

We have said that the size of the opening of the pupil probably influenced the mechanism of vision: after removing the cornea, the size of the pupil may be readily increased by a circular incision of the iris. The image in this case also appears to increase.

As the use of the crystalline is to augment the brilliancy and neatness of the image by diminishing its size, the absence of this body must be expected to produce a contrary effect.

After the extraction or depression of the crystalline in a similar way, in operating for cataract, the image is still formed at the bottom of the eye, but increases considerably; it becomes at least four times larger than that produced by an entire eye placed in the same relation with the object; it is ill defined, and its light extremely faint.

If the aqueous humour, crystalline, and transparent cornea are removed, and the capsule of the crystalline and the vitreous humour alone left with the coats, no image is formed upon the retina; the light reaches it, but produces no form corresponding with that of the body from which it proceeds.

Most of these results accord very well with the theory of vision received at present. One, however, does not—the distinctness of the image. Whatever be the distance of the object, the eye ought, according to theory, to change its form for the object to become distinct, or at least the crystalline should be carried forwards or backwards, according to the distances.* Here experiment is in contradiction to theory, which renders nugatory all the explanations hitherto proposed.

We should be wrong in supposing things to proceed

* These changes in the form of the eye or the position of the crystalline, have been successively ascribed to the compression of the globe of the eye by the straight and oblique muscles, to the contraction of the crystalline, to that of the ciliary processes, &c. Lately, M. Jacobson has attributed them to the entrance of the aqueous into the *canal goudronné*, or its exit from this canal.

exactly in the living as in the dead subject. One remarkable difference is, that in the living animal, the pupil increases or diminishes according to the intensity of the light, and perhaps according to the distance. Observation shows, that when an object is very brilliant, the pupil contracts to an opening scarcely visible, which must diminish the size of the image. On the other hand, when the light coming from an object is inconsiderable, the pupil greatly dilates, which must produce an enlargement of the image.

Motions of the Iris.

Some contend that the dimensions of the pupil vary with the distance of the object. This is not fully demonstrated; the influence of the intensity only of light has hitherto been distinctly remarked.

The mechanism of the motion of the iris has much engaged the attention of physiologists: some admit muscular fibres in it, and have explained its motions by their action: others have regarded them as of a perfectly peculiar nature. Mery and Haller have compared this phenomenon to that of erection. According to them, the motion of the iris is excited sympathetically by the action of light upon the retina. Lately, M. Maunoir, of Geneva, has discovered two layers of fibres in the iris, one of which occupying the circumference, he calls radiated; the other irregularly concentric and forming the centre of this membrane, he calls pupillary muscle. M. Maunoir regards these fibres as muscular, but gives no satisfactory proof of his opinion.*

* The pupil is very large in persons debilitated by venereal excesses, in those who labour under worms, some abdominal enlargement, hydrocephalus, &c.; and after the application for some hours of narcotics,

In some individuals the motions of the pupil are said to have been voluntary; and naturalists relate that some birds, as paroquets and night birds, exhibit the same phænomenon.

A bundle of light directed upon the iris causes no motion in it, and probably because its nerves belong to the system of ganglia.

The section of the iris in some operations is not painful, but has been known to excite vomiting.

The irritation of the iris with a cataract needle, produces no sensible motion, as I have ascertained by experiment.

Messrs. Fowler and Rinhold have found that galvanism directed upon the eye of man and animals produces contractions of the iris. Dr. Nysten has observed the same in the bodies of persons just executed. But are we to conclude with these writers, that the motions of the iris are muscular? I think not. In these experiments, the retina, no less than the iris, has been subjected to galvanism, and nothing proves the contraction of the iris not to have been the effect of the irritation of the retina.

Uses of the Choroid.

The choroid is subservient to vision chiefly by the black matter with which it is impregnated and which absorbs the light immediately after it has passed through the retina. This opinion is confirmed by what occurs in persons in whom some of the vessels of this membrane are become

and especially of belladona, to the conjunctiva; it is frequently either very large or very much contracted in cerebral affections. The motions of the pupil generally indicate the sensibility of the retina. The consideration of the state and motions of the pupil, is highly useful in medicine.

varicose: the dilated vessels remove the black matter which covered them, and as often as the image of the object falls upon the point of the retina corresponding with these vessels, the object appears tinged with red.

The condition of vision in albino men and animals, whose choroid and iris are not coloured black, still further supports this opinion: for in them vision is extremely imperfect: in the day-time, they can scarcely see sufficiently to go about.

Mariote, Le Cat, and some others, have allowed the power of perceiving light to the choroid. This opinion is altogether destitute of proof.

Uses of the Ciliary Processes.

We have but very vague notions of the office of the ciliary processes. They are generally considered contractile; some think them subservient to the motions of the iris, others to moving the crystalline forwards. M. Jacobson says, that their use is to dilate the openings which, according to him, exist in the front of the *canal goudronné*, so as to allow a portion of the aqueous humour to enter this canal, by which the crystalline must be displaced. Some believe that the ciliary processes secrete the black matter of the posterior surface of the iris and of the choroid, or even a portion of the aqueous humour.

M. Edwards, in a memoir upon the Anatomy of the Eye, has lately said, that they chiefly contribute to the secretion of the aqueous humour.* M. Ribes maintains the same opinion, and adds, " *that the ciliary processes*

* The celebrated Thomas Young, Secretary of the Royal Society of London, some years ago published an opinion similar to that of M. Edwards. See the *Philosophical Transactions.*

support life and motion in the crystalline and vitreous humour." Some animals, however, have these humours, but have no ciliary processes. Haller thinks their use is to preserve the crystalline in the most advantageous position. According to this anatomist, they adhere to the crystalline capsule both by their point and posterior side, by means of the black matter which covers them.

Action of the Retina.

If we speak here separately of the action of the retina in vision, it is to facilitate the study of this function; in reality, it is not possible to separate the action of this part from that of the optic nerve, and still less from that of the brain.

The action of the retina is a vital action, the mechanism of which is completely unknown.

The retina receives the impression of light when it is within certain limits of intensity. Too weak a light is not felt by the retina, and too strong a light injures it and incapacitates it for seeing.

When too strong a light has suddenly struck the retina, the impression is called *dazzling*, and the retina is incapable for a few moments afterwards of discovering the presence of light. This happens when we endeavour to look steadily at the sun.

When we have been long in the dark, even a faint light causes dazzling.

If the light which reaches the eye is extremely weak, and we endeavour to fix objects, the retina becomes very much fatigued, and we soon experience a painful sensation in the orbit, and even in the head.

A light of no very great intensity, acting for a certain time on a determinate point of the retina, renders it at length insensible in this point. When we look for some time at a white spot on a black ground, and afterwards direct our eyes to a white ground, we seem there to see a black spot, because the retina has become insensible in the point which was previously fatigued by the white light.

Conversely, after one point of the retina has been some time free from action while the rest were acting, the point which remained in repose acquires a greater degree of sensibility, whence objects appear spotted.

In this way it is explained why after looking for some time at a red spot, white bodies seem spotted green: in this case the retina has become insensible to the red ray, and we know that a ray of white light deprived of the red ray produces the sensation of green.

Analogous phænomena occur when, after looking steadily at a body of a red or any other colour, we look at bodies that are white or differently coloured.

We readily discover the direction of the light received by the retina. We instinctively believe that light moves in a straight line, and that this line is a prolongation of that in which it penetrated the cornea. And as often as the course of light has been modified, before arriving at the eye, the retina gives us inexact ideas. From this cause in a great measure optical deceptions arise.

The retina may receive at the same time impressions in every one of its points, but then the sensations which result are not very exact. It can be affected by the image of only one or two objects, although a great number are painted upon it; vision is then more distinct.

The centre of the retina appears to enjoy a more lively sensibility than the rest; and it is upon this part that we throw the image, when we wish to examine an object with attention.

Does light act upon the retina simply by contact, or does it traverse this membrane? The presence of the choroid, or rather of the black matter which covers it, must incline us to the latter opinion.

The point corresponding with the centre of the optic nerve, is said to be insensible to the impression of light. I am acquainted with no fact which directly proves this assertion.*

Action of the Optic Nerve.

There is no doubt that the optic nerve instantaneously transmits the impression of light upon the retina to the brain; but by what mechanism, we are quite ignorant.

The mode in which the optic nerves mix upon the sphenoid bone, must doubtless have great influence upon the transmission of impressions received by the eyes; but it is difficult to form any probable conjectures on this point.

Action of the two Eyes.

Notwithstanding all that has been said at different times, and the late efforts of Gall to prove that we never see but with one eye, it seems demonstrated, not only that the two eyes contribute to vision at the same time, but that this is absolutely necessary for certain very important acts of this function. There are however cases

* If the experiment of Mariote, mentioned in all physical works, were exact, which I doubt, it would be wrong, in my opinion, to conclude from it, that the retina is insensible in the part corresponding to the centre of the optic nerve.

in which it is advantageous to employ but one eye; for instance, when we endeavour to judge correctly of the direction of light, or of the situation of a body relatively to ourselves. Thus we shut one eye when firing a gun, when placing a series of bodies on a level in a straight line, &c. Another case in which it is very advantageous to employ only one eye, is when the two organs are unequal either in refracting power or sensibility. For the same reason we shut one eye when we use a glass.

But, with these exceptions, it is of the greatest importance to use both eyes at once. The following experiment of my own, appears to me to prove that both eyes see the same object at once.

Receive the image of the sun upon a plane in a dark room: take pretty thick glasses, each of one of the prismatic colours, and place them before your eyes; if you have a good sight, and especially if both your eyes are of equal strength, the image of the sun will appear of a dirty white, whatever may be the colour of the glass which you employ. If one of your eyes is much stronger than the other, you will see the image of the sun of the same colour as the glass you look through with the strongest eye. These results have been verified in the presence of M. Tillaye, jun. in the physical chamber of the Faculté de Medecine.

The same object really produces two impressions, but the brain perceives only one of them. For this effect, however, the motions of the eyes must be harmonious. If after some disease, the motions of the eyes are no longer regular, we receive two impressions of the same object, which occurrence constitutes squinting. We may at pleasure receive two impressions of one object: it is sufficient voluntarily to destroy the harmony of the motions of the eyes.

Estimation of the Distance of Objects.

Vision results essentially from the contact of light with the retina, yet we always refer the cause of the sensation to the bodies from which the light proceeds, and which are often very distant. This result must evidently be the effect of an intellectual operation.

We judge very differently of the distance of bodies according to its degree; we judge correctly when they are near, not when they are distant; then our judgments are frequently erroneous; but when objects are very distant, we are constantly in error.

The united action of both eyes is absolutely necessary in judging correctly of distance, as the following experiment proves.

Suspend a ring by a thread, and fix a hook easily able to enter it, to the end of a long stick: place yourself at a proper distance, and endeavour to put the hook into the ring: if you use both eyes, you will succeed every time; if you shut one eye, you will not; the hook will go too far or fall short of the ring, and you will succeed only by chance and after much blundering; persons with eyes of unequal power, do not succeed even when they use both eyes.

If a person by accident loses an eye, he will sometimes be a year before he can judge correctly of the distance of bodies placed near him.* In general, persons with but one eye judge imperfectly of distance. The size of the object, the intensity of its light, the presence of in-

* I have seen a very remarkable fact of this kind; the person was for many months after the accident obliged to grope about before he could seize a body within his reach.

termediate bodies, considerably influence our judgment of distance.

Our judgment is much more exact when objects are on the same level with ourselves. Thus, when we look from the top of a tower upon objects below, they seem much smaller than they appeared at the same distance, when on the same level with ourselves. It is the same when we look at objects placed above us. Hence the necessity of giving a considerable size to objects intended to be placed on the top of edifices and seen at a distance. The smaller the dimensions of an object are, the nearer it must be placed to the eye to be seen distinctly. We see a horse distinctly at the distance of ten metres, but should not even descry a bird at the same distance. If I wish to examine a hair or a feather of these animals, the eye requires to be very near. However, the same object may be seen distinctly at very different distances; for instance, it is indifferent to many persons, whether they place the book which they are reading, at the distance of one or two feet from their eyes; the intensity of the light which illuminated an object has much influence upon the distance at which it can be seen distinctly.

Estimation of the Size of Bodies.

The manner in which we arrive at a correct judgment of the size of bodies, depends more upon the understanding and upon habit, than even upon the apparatus of vision.

We form our judgments relative to the dimensions of bodies, from the size of the image formed at the bottom of the eye, the intensity of the light which proceeds from the object, the distance at which we suppose it placed, and especially from our habit of beholding similar objects. For this reason we judge with difficulty of the size of a body which we see for the first time, when we do not consider its distance. A distant mountain, when first seen, generally appears much smaller than it really is; hence we believe ourselves near it, when in fact we are at a great distance.

Beyond rather a considerable distance, we fall into an inevitable delusion: objects appear infinitely smaller than they really are; this happens with respect to the heavenly bodies.

Estimation of the Motion of Bodies.

We judge of the motion of a body by that of its image upon the retina, and by the variations of the size of this image, or, what comes to the same thing, by the change of the direction of the light which reaches the eye.

For us to be able to follow the motion of a body, it must not move too rapidly, for then we should not perceive it, as happens in projectiles sent by gunpowder, especially when they pass near us. When they move at a distance from us, as they send light to the eye for a long time, because the field of vision is larger, we easily perceive them. To judge correctly of the motion of bodies, we must not be in motion ourselves.

When bodies are at a great distance which are leaving or approaching us, we perceive their motions with difficulty. In fact, we judge of their motion, in this case, merely by the variation in the size of the image. But as this variation is infinitely small when the body is very distant from us, it is very difficult, or even sometimes impossible, for us to estimate it.

In general we discover with difficulty, or find it impossible to discover, slow motions of bodies. Whether this effect depends upon the absolute slowness of motion, as in the case of the hour-hand of a watch, or results from the slowness of the motion of the image, as happens with the fixed stars and very distant objects.

Of optical Illusions.

After what has been just said of the manner in which we judge of the distance, size and motions of bodies, it is easy to conceive that sight may often lead us into errors.

These errors are known in physics and physiology by the title of *optical illusions*. We judge, in general, sufficiently well of bodies placed near us; but we are frequently deceived with respect to those at a distance.

The illusions into which we fall with respect to neighbouring bodies, depend either on the reflection, or refraction which the light undergoes before reaching the eye, and upon the law which we establish instinctively, viz. that the course of light is always in a straight line. This is the cause of the errors occasioned by mirrors: we see objects behind plain mirrors exactly in the prolongation of the ray which arrives at the eye. From the same cause arises the apparent increase or diminution of the size of a body seen through a glass. If this makes the rays converge, the body will seem larger; if it makes them diverge, it will seem smaller. The use of these glasses produces also another illusion; objects appear surrounded by the colours of the solar spectrum, because the surfaces of the glass not being parallel, decompose light in the manner of the prism.

Distant objects continually produce illusions which are inevitable, because resulting from certain laws of the animal economy. An object appears nearer in proportion as its image occupies a more considerable space upon the retina, or as the light which proceeds from it is more intense. Of two objects of different size, but equally bright and distant, the larger will appear the nearer, unless particular circumstances occur to enable us to judge correctly of the distance. Of two objects of equal volume and distance, but unequally illuminated, the brighter will appear the nearer; it would be the same if the objects were at unequal distances, as we may convince ourselves by looking at a row of reflectors; if one is more brilliant, it will appear the first of the row, while that which is really the first will appear the last, if it is the least brilliant.

The same object, seen with nothing intervening between it and ourselves, always appears nearer than when there are between us and it bodies which may influence our judgment of its distance.

When our eyes are struck by an illuminated object, while the surrounding ones are in obscurity, this object appears much nearer than it really is. This is the effect of light at night.

Objects appear smaller as they are more distant. Thus trees forming a long grove, appear smaller and nearer to each other, in proportion to their greater distance.

By observing all these illusions, and the laws of the animal economy upon which they depend, art is enabled to produce them at pleasure. Painting, for instance, does nothing more in certain cases than transport upon the canvas the optical errors into which we habitually fall.

The construction of optical instruments is also founded upon these principles; some augment the intensity of light coming from objects; others render it divergent or convergent, to increase or diminish the apparent size of objects, &c. &c.

Some illusions we dissipate by practice, as the very curious history of the blind person given by Cheselden proves.

This celebrated English surgeon restored sight by a surgical operation * to a very intelligent person who had been blind from his birth, and observed the mode in which sight was developed in this young man. " When he saw light for the first time, he was so far from being able to judge of distance, that he imagined all objects were in contact with his eyes (this was his expression), just as objects which he felt touched his skin. The most agreeable objects were those whose shape was even and figure regular, although he could not judge of their form, nor say why they appeared more agreeable than others. During his blindness, his ideas of colours had been so faint, that he could now distinguish by a strong light that they had not left traces sufficient for him to recognize them; he did not know the form of any object, and could not distinguish one thing from another, however different their figure and size. When he was shewn objects which he had known previously by touch, he looked at them with attention, and carefully observed them, that he might recollect them at another time; but as he had too many objects to retain at once, he forgot the greater number of them; and when he first learned, as he said, to see and recollect objects, he forgot a thousand for one that he retained. More than two months elapsed before he could recollect that pictures were solid bodies; till that period he considered them as only differently coloured planes,

* This is commonly supposed to have been the operation for cataract, but there is every reason to think that the operation performed on this young man was the incision of the membrana pupillaris.

and surfaces diversified by the variety of their colours; but when he began to conceive that these pictures represented solid bodies, he expected to find these solid bodies by touching the canvas; and was greatly surprised, when, on touching the parts which from light and shade appeared to him round and unequal, he found them flat and even like the rest. He inquired which sense deceived him, sight or touch. A small portrait of his father was then presented to him, lying in his mother's watch case; he said, that he knew very well that it was his father's likeness, but asked, with great astonishment, how so large a face could be contained in so small a place: it appearing to him as impossible as to put a bushel into a pint. At first he could bear a very weak light only, and saw every object extremely large; but in proportion as he saw larger things, he judged the first to be smaller; he thought that nothing existed beyond the limits of what he saw. The same operation was performed a year afterwards upon the other eye, and equally succeeded. At first he saw objects much larger with this eye than with the other, but not so large as he had seen them with the first eye; and when he looked at the same object with both eyes at once, he said that this object appeared as large again as with his first eye, but he did not see double, or at least we could not convince ourselves that he had seen objects double, when he had obtained the use of his second eye."

This case is not solitary; a number of others exist, and all with the same results. I think we may draw from them this inference, that our exact ideas of the distance, size, form, &c. of objects, are the result of practice, or what amounts to the same thing, of the education of the sense of sight: an inference confirmed by the consideration of the sight at different ages,

Vision at different Ages.

The eye is one of the first parts formed in the fœtus. In the fœtus, the eyes appear as two black spots. At seven months they are already capable of modifying light, so as to form an image upon the retina, as I have ascertained by experiment. Till this period, the eyes could not fulfil this purpose, because till then the pupil is closed by the membrana pupillaris.* At seven months this membrane disappears; it is commonly said to split, but probably is absorbed. This too is the time when the fœtus can live. Fœtal eyes, however, are found, which at six or even five months offer no traces of this membrane.

There are some differences between the eye of the fœtus and of the adult; but they are not very remarkable. In the former, the sclerotic is finer, and even slightly transparent; the choroid is red without, and the black tint of its inner surface is less intense; the retina is proportionally more developed; the aqueous humour is more abundant, whence a greater projection of the cornea; lastly the crystalline is far less consistent than in the adult. Before birth the eyelids are close, and, as it were, glued to-

* According to M. Edwards, the membrana pupillaris is formed by a prolongation of the membrane of the aqueous humour, and of the external lamina of the choroid. According to the same anatomist, there is no aqueous humour in the anterior chamber before the rupture of the membrana pupillaris, and this humour is accumulated in the posterior chamber; which proves, 1st, that the membrane of the aqueous humour does not secrete it; 2dly, that this organ exists in the posterior chamber; 3dly, that before the seventh month, the membrane of the aqueous humour presents all the characters of serous membranes, and particularly that of forming a close sac.

gether. (In some animals they are even united by the palpebral conjunctiva, which passes from one to the other, and does not split till after birth.)

As age advances, the quantity of the humours insensibly diminishes till the adult period ; after this it diminishes in a more striking manner. This diminution is particularly evident in old age.

The crystalline in particular becomes not only more dense, but inclines to a yellow colour, at first clear, and afterwards deeper. While it undergoes this change, it acquires a greater hardness, and contracts a slight opacity, which may proceed with age till it amounts to a complete opacity.

The eye is therefore well adapted, in the new-born infant, to act upon light, and images are formed upon the retina, as experience demonstrates. However, during the first month, the child gives no sign of being sensible to light; its eyes move but slowly and in an uncertain manner; it is not even till towards the seventh week, that it begins to give proofs of sensibility. A brilliant light only is at first capable of striking and interesting it; it seems pleased with looking at the sun; soon it becomes sensible to the mere light of day. It does not yet, however, distinguish any object: the first which strike it are red; and in general it prefers the strongest colours. At the end of some days, it fixes its attention upon bodies whose colours it can distinguish, but has no idea of distance or size. It stretches forth its hand to seize the most distant objects; and as the first of its wants is to feed itself, it carries to its mouth every object that it seizes, of whatever dimensions. Thus vision is very imperfect at the first period of life; but by practice, and especially by the conclusions which the continual errors into which it falls compel it to draw, its sight becomes perfected really by education.

Infants have been thought to see objects double or reversed; but nothing proves this assertion. It is also said, and with more reason, that as the refracting parts of the eye are more abundant, they ought to see objects smaller than they in fact are.

Vision soon acquires all the perfection of which it is susceptible, and in general undergoes no modification till towards the commencement of old age. Then it is that the change above mentioned in the humours of the eye tends to render it less distinct; but what contributes to weaken it, is the diminution of the sensibility of the retina.

Three causes combine to alter vision in the old man: first, the diminution of the quantity of the humours of the eye, a circumstance which by diminishing the refracting power of the organ, makes the old man no longer able accurately to distinguish near objects, and obliges him either to remove them from him, that he may see them, because in this way the light penetrating the eye is less divergent, or to employ convex glasses, which diminish the divergence of the rays. Secondly, the commencing opacity of the crystalline, which disorders vision, and tends, by increasing, to produce blindness, causing the disease known under the name of cataract. Thirdly and lastly, the diminution of the sensibility of the retina, or, if you please, of the brain, which opposes the perception of impressions produced upon the eye, and leads to complete and incurable blindness.

HEARING.

Hearing is a function intended to acquaint us with the vibratory motions of bodies.

Sound is to the ear what light is to the eye. Sound results from the impression produced on the ear by a vibratory motion impressed upon the particles of a body by percussion or any other cause. This word signifies also the vibratory motion. When the particles of a body have been thus put in motion, they communicate it to the surrounding elastic bodies; these do the same, and the vibratory motion is gradually propagated sometimes to a great distance. Only elastic bodies in general can produce and propagate sound; but solid bodies usually produce it, while the air is most frequently the vehicle of its transmission to the ear.

In sound we distinguish *intensity, tone* and *note, (timbre.)*

Intensity depends upon the extent of the vibrations.

Tone depends upon the number of vibrations produced in a given time, and in this respect is divided into *acute* and *grave.*

Grave sound arises from few, acute from numerous vibrations.

The gravest sound which the ear can perceive, is formed of two thousand vibrations in a second; the most acute of twelve thousand. Appreciable sounds, i. e. sounds with vibrations capable of being instinctively ascertained by the ear, range within these two limits. Noise differs from appreciable sound, in the ear not distinguishing the number of its component vibrations.

An appreciable sound composed of twice the number of the vibrations of another, is called its octave. Between those two are seven intermediate sounds, constituting the diatonic scale or gammut; they are denoted by the names, *ut, re, mi, fa, sol, la, si.*

When a sonorous body is put in motion by percussion, we hear first a distinct sound, more or less intense, more or less acute, &c. according to circumstances; this is the *fundamental* sound: by a little attention we discover at the same time other sounds. These are called *harmonic*. This remark is easily made on twanging the chord of an instrument.

The *note* depends on the nature of the sonorous body.

Sound is propagated across elastic bodies. The quickness of its progress varies according to the propagating body.

Sound travels a hundred and forty-two feet per second. Its transmission is still more rapid through water, stone, wood, &c. During propagation it in general loses its force in the direct ratio of the square of the distance; this is true at least in regard to air. It may also acquire intensity during propagation, as when it travels through very elastic bodies, as metals, wood, condensed air, &c. acute, grave, intense, weak sounds, &c. are propagated with equal rapidity and without confusion.

It is generally believed that sound is propagated in a straight line, forming cones analogous to those of light, with this essential difference, however, that the particles of sonorous cones have only an oscillatory motion, while those of luminous cones are really carried on.

When sound meets with a resisting body, it is reflected like light, i. e. forming an angle of incidence equal to the angle of reflection. The form of the reflecting body has the same influence upon sound.

The slowness of its propagation gives rise to certain phenomena which are easily explained. Such as the phenomenon of echo, of the mysterious chamber, &c.

Apparatus of Hearing.

The auditory apparatus is very complicated; we shall not dwell upon anatomical details, from which no advantage can result, for we yet know very little of the uses of the different parts which constitute this sense.

In the apparatus of hearing are found, as in the apparatus of vision, an assemblage of organs, which seem by their physical properties to contribute to the function, and behind them a nerve destined to receive and transmit the impression.

The auditory apparatus consists of the external ear, the middle ear, the internal ear, and the acoustic nerve.

External Ear.

Under this title we comprehend the *pavilion* (pavillon) and *external auditory meatus.*

The former is larger or smaller in different individuals. Its external surface, which projects a little forwards in a well formed ear, presents five eminences; the *helix*, *ante-helix*, *tragus*, *ante-tragus*, *lobule*, and three cavities, viz. that of the *helix*, the *fossa navicularis*, and the *concha*. The pavilion is formed of a fibro-cartilage, flexible and elastic; the skin which covers it is fine and dry, and adheres to the fibro-cartilage by a compact cellular membrane containing but little fat; the lobule alone contains a large quantity. Below the skin are numerous sebaceous follicles, which furnish a white and micaceous substance giving to the skin its polish, and in some degree its suppleness. In the various prominences of the pavilion, some muscular fibres are seen, which are termed muscles, but are in fact nothing more than vestiges.* The pavilion receives many nerves and vessels, is very sensible, and easily becomes red. It is attached to the head by ligaments, cellular membrane, and muscles, which from their position are called anterior, superior and posterior. These muscles are very much developed in many animals; in man they must be regarded as merely vestiges.

Auditory Meatus.

This canal extends from the concha to the membrana tympani; its length, varying with age, is about ten or twelve lines in the adult, is narrower in its middle than at its extremities, and presents a slight curve upwards and forwards. Its external orifice is commonly beset with hairs, like the entrances to other cavities. It is composed of an osseous portion, a fibro-cartilage uniting with that of the pavilion, and a fibrous part which completes it above. The skin dips into it, and at the same time becomes finer, and terminates by covering the external surface of the membrana tympani. Below this skin are many sebaceous follicles, which furnish the cerumen, a yellow, bitter, &c. matter, whose offices we shall hereafter mention.

Middle Ear.

The middle ear comprehends the cavity of the tympanum, the little bones contained in this cavity, the mastoid cells, the guttural canal, &c.

* The title of *vestiges* is given in anatomy to parts without use in the animal in which they are seen, and which only shew the uniform plan followed by nature in the formation of animals.

The cavity of the tympanum separates the external from the internal ear. Its form is that of a portion of rather an irregular cylinder. Its inner side above presents an oval opening which communicates with the vestibule, and is closed by a membrane; immediately below is a projection called promontory; below this projection, a little groove which lodges a twig of a nerve; still lower, an opening called fenestra rotunda, which corresponds with the outer turn of the cochlea, and is likewise closed by a membrane. This membrane is directed obliquely downwards and inwards, is tense, very fine and transparent, lined without by a projection of the skin, and within by the mucous membrane which lines the tympanum; it is also covered within by the nerve termed *chorda tympani:* its centre gives attachment to the extremity of the handle of the malleus; its circumference is fixed to the osseous extremity of the auditory canal, adheres to it equally in every point, and has moreover no opening to make a communication between the external and middle ear. Its substance is dry, fragile, and different from every other in the animal economy; we find in it neither fibres, vessels, nor nerves.

The circumference of the tympanum presents anteriorly, 1. the opening of the guttural canal, by which the tympanum communicates with the upper part of the pharnyx; 2. the opening by which the tendon of the internal muscle of the malleus enters. Behind we see, 1. the opening of the mastoid cells, which are winding canals, existing in the substance of the mastoid process, and always filled with air; 2. the pyramid, a little hollow prominence which lodges the muscle of the stapes; 3. the opening at which the chorda tympani enters the tympanum. Below, the tympanum presents a slit, called *glenoidal,* by which the tendon of the anterior muscle of the malleus enters and the chorda tympani goes out, in order to anastomose with the lingual nerve of the fifth pair. Above, the circumference offers only a few openings for the passage of blood vessels. The cavity of the tympanum, and all the canals which terminate in it, are lined with a very fine mucous membrane; this cavity, which is always full of air, contains also four little bones (the *malleus, incus, os lenticulare,* and *stapes,*) which form a chain from the membrana tympani to the fenestra ovalis, to which the base of the stapes is affixed. Some small muscles are provided for moving this chain, to stretch and relax the membranes in which it terminates: thus, the internal muscle of the malleus draws it forwards, bends the chain in this direction, and stretches the membranes; the anterior muscle produces the opposite effect; we may conceive that the little muscle which is lodged in the pyramid, and attached to the neck of the stapes, may give a slight degree of tension to the chain by drawing this towards itself.

Internal Ear, or Labyrinth.

It consists of the cochlea, semicircular canals, and vestibule.

The cochlea is an osseous cavity, twisted spirally, which circumstance entitles it to its name. This cavity is divided into two others, called *scalæ* of the cochlea, and distinguished into internal and external. The partition which separates them is a plate placed upon its smallest surface, and throughout its length is partly osseous and partly membranous. The external scala communicates with the tympanum by the fenestra rotunda, the interval terminates in the vestibule.

Semicircular Canals.

This is the appellation of three cylindrical canals, bent in a semicircle, two of which are horizontal, and the third vertical. The extremities of these canals terminate in the vestibule; they contain bodies of a grey colour, swelled at their ends.

Vestibule.

This is a central cavity, at which all the rest unite. It communicates with the tympanum by the fenestra ovalis, with the internal scala of the cochlea, with the semicircular canals, and with the internal auditory passage by a great number of small openings.

All the cavities of the internal ear are hollowed out of the hardest part of the petrous portion, and lined with an extremely fine membrane, and filled with a thin limpid fluid, called *liquor of Cotunni*, which can flow back by two small openings, known by the name of *aqueducts of the cochlea and vestibule;* they also contain the acoustic nerve.

Of the Acoustic Nerve.

This nerve arises from the fourth ventricle, and enters the labyrinth by the openings in the bottom of the internal auditory canal. On arriving at the vestibule, it splits into several branches, one of which remains in the vestibule, another enters the cochlea, and two are destined for the semicircular canals. The distribution of these various branches in the cavity of the internal ear, has been carefully described by Scarpa; details would be superfluous here.

While finishing this concise account, we remark that the internal and middle ears are traversed by many nervous filaments, whose presence in this part must serve some purpose in hearing: it is known that the facial nerve runs a considerable way in a canal hollowed in the substance of the petrous portion. In this canal it receives a twig of the vidian nerve, and it furnishes the chorda tympani, which is applied to the membrana tympani. Two other anastomoses also occur in the ear; one to which M. Ribes has lately directed the attention of anatomists; the other recently discovered by M. Jacobson.

MECHANISM OF HEARING.

Uses of the Pavilion.

It collects the sonorous rays and directs them towards the auditory canal, and this it does so much the better, as it is larger, more elastic, more detached from the head, and directed more forwards. Boerhaave pretended to have proved by calculation, that the sonorous rays which fall upon the external surface of the pavilion, are ultimately directed towards the auditory canal. This assertion is evidently incorrect, in regard to some pavilions, in which the antehelix projects more than the helix. How could rays falling on the posterior surface of the antehelix reach the concha? The pavilion is not indispensable to hearing, for in man and animals it may be removed without injury to hearing for more than a few days.

Uses of the Auditory Canal.

The canal transmits sound like any other canal, partly by the air within it, and partly by its sides, to the membrana tympani.—The hairs which it has, especially at its entrance, oppose the introduction of foreign bodies, as grains of sand, dust, insects, &c.

Uses of the Membrana Tympani.

This membrane receives the sound transmitted by the auditory meatus. In what circumstances is it stretched by the action of the internal muscle of the malleus? In what cases is it relaxed by the contraction of the anterior muscle of the malleus? We do not know: hitherto conjectures only have been formed on the subject.

An opening made in this membrane does little injury to hearing.* As this membrane is dry and elastic, it must transmit sound extremely well, on one hand to the air contained in the tympanum, and on the other to the chain of bones. The chorda tympani cannot fail to participate in the vibrations of this membrane, and transmit some impressions to the brain. We know that the contact of a foreign body with the membrane is excessively painful, and that a violent noise also causes acute pain. The membrane of the tympanum may be torn, or even totally destroyed, without any sensible derangement of hearing.

Uses of the Cavity of the Tympanum.

Its principal use is to transmit to the internal ear the sounds which it has received from the external. This transmission of sound by the tympanum takes place; 1, by the chain of bones, which acts particularly upon the

* For the different opinions of the uses of this membrane, see HALLER, T. v. p. 198, 199, seq.

membrane of the fenestra ovalis;* 2. by the air which fills it, and which acts upon all the petrous portion; but especially upon the membrane of the fenestra rotunda; 3. by its sides.

Uses of the Eustachian Tube.

The tube serves to renew the air of the tympanum; its obliteration is said to produce deafness.

It is wrong to imagine that it can conduct sounds to the internal ear; nothing supports this assertion: it gives vent to the air, whenever violent sounds strike the tympanum, and permits the renewal of that which fills the tympanum and mastoid cells. The air contained in the tympanum, being very rarified, is calculated to diminish the intensity of the sounds which it transmits.

Uses of the Mastoid Cells.

The use of the mastoid cells is not well known; they are suspected to augment the intensity of the sound which reaches the tympanum. If they produce this effect, it must be rather by the vibrations of the laminæ which separate the cells, than by those of the air which they contain.

Sound may arrive at the tympanum in other ways besides the auditory canal: shocks on the bones of the head are directed towards the temple, and perceived by the ear.

* We are entirely ignorant of the use of the movements which may be impressed on the chain. The loss of the bones, except of the stapes, does not necessarily produce loss of hearing; however, we think we have remarked, that individuals so circumstanced do not preserve this sense beyond two or three years.

All know that the ticking of a watch placed between the teeth is heard distinctly.

Uses of the Internal Ear.

We know but little of the functions of the internal ear; but it may be conceived, that sonorous vibrations are propagated to it in several ways, but principally by the membrane of the fenestra ovalis, by that of the fenestra rotunda, and by the inner portion of the tympanum; and that the liquor of Cotunni experiences vibrations, which are transmitted to the acoustic nerve. We may also conceive how important it must be for this fluid to yield to vibrations which are too intense, and might injure this nerve. It may in this case flow back into the aqueducts of the cochlea and vestibule, which in this respect would evidently be very analogous to the Eustachian tube.

The external scala of the cochlea must receive vibrations chiefly by the membranes of the fenestra rotunda; the vestibule by the extremity of the chain of bones; the semicircular canals by the sides of the tympanum, and possibly by the mastoid cells, which are frequently prolonged beyond these canals; but we are altogether ignorant of the use of each part of the internal ear in hearing.

The osseo-membranous partition of the scalæ of the cochlea, gave rise to hypotheses at present universally rejected.

Action of the Acoustic Nerve.

The acoustic nerve receives the impressions and transmits them to the brain; the latter perceives them with more or less promptitude and exactness in different individuals. Many persons have a false ear, i. e. cannot distinguish sounds with accuracy.

The action of neither the acoustic nerve nor the brain in hearing, is explained, but some observations may be made on this point.

Sounds, to be perceived, must be within certain limits of intensity; a sound if too strong hurts us, if too weak produces no sensation. We can perceive a great number of sounds at once. Sounds, especially if appreciable, combined and succeeding each other in a certain manner, are a source of agreeable sensations. An art consists in disposing sounds, so as to produce this result; this art is *music*. Certain combinations produce, on the contrary, disagreeable impressions; very acute sounds hurt the ear, very intense and very grave sounds lacerate the membrane of the tympanum. The absence of the liquor of Cotunni destroys hearing. When a sound is very much prolonged, we think we hear it long after it has ceased.

Action of the two Apparatus.

We receive two impressions, but perceive only one. It has been incorrectly said, that we use but one ear at a time. Indeed, when sound arrives directly at one ear, it is seized much more easily by it, and more difficultly by the other, and in these cases we employ but one ear; and when we listen attentively to a sound which we are afraid of not hearing, we contrive to let the rays enter the concha directly; but when we have to judge of the direction of a sound, i. e. to decide upon the part from which it proceeds, we are obliged to employ both ears, for it is only by comparing the intensity of the two impressions, that we can discover the source of the sound.

If, for instance, we completely stop up one ear, and order a slight noise to be made at some distance from us, in a dark place, it will be impossible to judge of the direction of the sound ; but we shall readily succeed by employing both ears. Sight is of great use in these decisions, for it is often impossible in the dark, even when we use both ears, to decide upon the part from which the sound comes.

Sound may also enable us to judge of the distance of the body which produces it, from ourselves ; but in order to judge accurately, the nature of the sound must be familiar to us, for without this condition, our judgments are always erroneous. In this case we judge according to this principle, *that a very intense sound comes from a neighbouring body, and a weak sound from a distant body* ; if an intense sound proceeds from a distant, or a weak sound from a neighbouring body, we fall into errors of hearing. We are in general easily deceived as to the source of a sound ; sight and reason are of great assistance in forming our opinion.

The different degrees of convergence or divergence of the sonorous rays, do not seem to influence hearing, nor do we modify the cause of them for any other purpose, than to throw a large portion of them into the ear; which is the use of hearing-trumpets, employed in difficulty of hearing. It is sometimes necessary to diminish the intensity of sounds ; in this case we place a soft and but slightly elastic body in the auditory canal.

Modifications of hearing by Age.

The ear is formed early in the fœtus. At birth, all that belongs to the internal ear, and the bones are nearly such as they remain subsequently ; but the other parts of the middle and external ear are not yet in a condition to act, whence a great difference subsists between the eye and ear. The pavilion is proportionally very small; soft, consequently not very elastic, and altogether unfit to perform the functions ascribed to it. The sides of the auditory canal are of the same structure as the pavilion; the membrana tympani is very oblique, and in some degree a continuation of the superior part of the canal; it is consequently badly disposed to receive the sonorous rays. All the external ear is covered by a white soft matter, offering still further obstacles to the performance of its functions. The cavity of the tympanum is rather smaller in proportion; instead of air, it contains a thick mucus. The mastoid cells do not exist. In the progress of age the auditory apparatus quickly acquires the state in which we have described it to exist in the adult. In old age the physical changes which it undergoes, far from being, like those of the eye, unfavourable, seem, on the contrary, to perfect it; every part becomes harder and more elastic; the mastoid cells extending to the summit of the petrous portion, thus surround all the cavities of the internal ear.

The strongest sounds do not sensibly affect the new-born child; after some time it appears to perceive acute sounds; and nurses choose sounds of this kind to attract its attention. A long period elapses before the child can judge correctly of the intensity and direction of sound, and particularly before it is able to attach a meaning to different articulate sounds. As it prefers a strong light, so it for a long time prefers the most acute and intense sounds.

Although the auditory apparatus grows perfect with age, it is however certain that hearing becomes difficult at the beginning of old age, and that few old men are not more or less deaf. This circumstance appears to depend on the one hand upon the diminution of the fluid of Cotunni, and on the other upon the gradual diminution of the sensibility of the auditory nerve.

SMELL.

Most bodies allow excessively small particles to escape, which diffuse themselves in the atmosphere, and are sometimes carried in it to a considerable distance. These particles constitute odours; a sense is destined to know and examine them, and thus an important relation established between animals and substances.

Bodies whose particles are fixed are termed inodorous.

There are great differences among odorous bodies, as to the mode in which the odours escape; some allow their escape only when heated; others, only when rubbed; some give only a very faint, others only a very strong smell. Such is the tenuity of odorous particles, that a body may disengage them for a very long period without sensibly losing weight.

Every odorous body has a peculiar odour. As these bodies are very numerous, an attempt has been made to class odours; but every attempt of this kind has been equally unsuccessful. They can hardly be distinguished into any others than *weak, strong, agreeable* and *disagreeable.* We also observe odours to be *musky, aromatic, fœtid, virulent, spermatic, pungent, muriatic,* &c. Also fugitive and tenacious. In most cases we can describe an odour only by comparing it to that of some well known substance.

Odours have been said to possess nutritive, medicinal, and even poisonous properties; but in the cases which have given rise to these opinions, has not the influence of odours been confounded with the effects of absorption? A man after pounding jalap for some time will be purged as if he had swallowed it. These effects ought not to be ascribed to the odour, but to the particles diffused in the atmosphere and introduced into the circulation, either with the saliva or the air which we inspire: to the same cause must be attributed the intoxication of persons exposed for some time to the vapour of spirituous liquors.

The air is the ordinary vehicle of odours, and transports them to a distance; but they may be propagated likewise in a vacuum, and certain bodies project odourous particles with some force. This subject has not been attentively studied; we do not know whether in the progress of odours there is any circumstance anologous to the convergence or divergence, the reflection or refraction of the luminous rays. Odours may be attached to or combined with many liquids and solids. This method is employed to fix or preserve them for a length of time.

Liquids, vapours, gases, and many solids reduced to an impalpable, or even coarser powder, have also the property of acting upon the organs of smell.

Apparatus of Smell.

The olfactory apparatus must be regarded as a kind of sieve, placed over the course which the air most frequently takes in passing to the chest, and intended to retain all foreign bodies mixed with the air, and particularly odours.

This apparatus is extremely simple; it differs essentially from that of sight or hearing, its nerve having no part before it calculated physically to modify the excitant: the nerve is in some sense naked. The apparatus consists of the pituitary membrane which lines the nasal canals, of the membrane which lines the sinuses, and of the olfactory nerve.

The pituitary membrane covers the whole extent of the nasal fossæ, greatly increases the thickness of the cornets, and is prolonged beyond their edges and extremities, so that the air is compelled to traverse the nasal fossæ by very narrow and long routes. This membrane is thick, and adheres closely to the bones and cartilages which it covers. Its surface presents an infinity of little prominences, considered by some as nervous papillæ, by others as mucous crypts, but which are in all appearance vascular. These prominences give the membrane an appearance of velvet. The pituitary membrane is smooth and soft to the touch, and receives a large number of vessels and nerves.

The passages through which the air arrives at the fauces merit some attention.

They are three in number, and distinguished by anatomists under the appellations of *meatus inferior, superior*, and *medius*. The inferior is the largest and longest, and the least oblique and tortuous; the middle meatus is narrower, nearly as long, but extended more from above downwards; the superior is much shorter, more oblique, and still more narrow. To these passages must be added the very narrow interval which separates the septum of the nostrils through its whole extent from the external parietes. Such is the narrowness of all these canals, that the least swelling of the pituitary membrane renders the course of the air through the nostrils difficult, or even impossible.

Cavities more or less spacious, hollowed out of the substance of the bones of the head, and named *sinuses*, communicate with the two superior meatus. These sinuses are the *maxillary*, the *palatine*, the *sphenoidal*, the *ethmoidal*, the *frontal*, and those which are in the body of the ethmoid bone, more commonly known by the title of *ethmoidal sinuses.*

These sinuses communicate with only the two superiour meatus. The frontal and maxillary sinus, and the anterior cells of the ethmoid bone, open into the middle meatus; the sphenoidal and palatine sinus, and the posterior ethmoidal cells, open into the superior meatus. The sinuses are lined by a fine, soft membrane, not very strongly attached to them, and apparently of the mucous kind. It secretes more or less abundantly a matter called *nasal mucus*, which is continually shed over the pituitary membrane, and appears useful in smelling. The great extent of the sinuses seems to correspond with a greater perfection of smell; this, at least, is one of the most positive results of comparative anatomy.

The olfactory nerve arises by three distinct roots from the posterior, inferior, and inner part of the anterior lobe of the brain. At first prismatic, it runs towards the cribriform-plate of the ethmoid bone; there it suddenly swells, and then splits into a great number of branches which are distributed upon the pituitary membrane, and principally upon its upper part.

It is important to remark, that the branches of the olfactory nerve have not been traced upon the inferior cornet upon the inner surface of the middle, nor in any of the sinuses. The pituitary receives not only the first pair, but a number of filaments which arise from the spheno-palatine ganglion; these are distributed in the meatus, and at the lower part of the membrane. It covers also for some extent the ethmoidal branch of the nasal nerve, and receives a large number of filaments from it. The membrane of the sinuses also receives some nervous twigs.

The nasal cavity opens outwardly by means of the nostrils; the form, size, and direction of which are subject to much variation.

The nostrils are beset inwardly with hairs, and have the power of increasing by muscular action. The nasal fossæ open into the pharynx by the posterior nostrils.

Mechanism of Smell.

Smell occurs essentially when the air is running through the nasal fossæ to the lungs. We seldom perceive odours when the air is coming from the chest; it however occasionally happens, particularly in organic affections of the lungs.

The mechanism of smell is extremely simple; it is merely necessary that odorous particles be arrested on the pituitary membrane, particularly on those parts where it receives the branches of the optic nerve. As it is exactly in this upper part of the nasal fossæ that the passages are narrowest, and most abound in mucus; it is also natural for the particles to be stopped there. We may also conceive the use of the mucus: from its physical properties, it appears to have a greater affinity to odorous particles than to air; it separates them from this fluid, and arrests them upon the pituitary membrane, where they produce the impression of odours; it is likewise very important for the exercise of smell, that the nasal mucus preserve the same physical properties; as often as these are changed, as we observe in different degrees of coryza, smell ceases or becomes imperfect.* After what we have said of the distribution of the olfactory nerves, it is evident that the odours which the upper part of the nasal cavities contains, will be more easily and strongly perceived; hence we modify inspiration so that the air may be directed towards this point when we wish to smell a body strongly or accurately. Hence, too, those who take snuff, endeavour to carry it towards the vault of the nasal fossæ. The internal surface of the cornets appears very well calculated to arrest odours while the air is passing; and as the sensibility is there very great, we are induced to believe that smell takes place there, although we are unable to trace the branches of the first pair so far.

Physiologists have not yet settled the use of the nose in smell; it appears intended to direct the air charged with odours towards the upper part of the nasal fossæ. Persons whose nose is deformed, and especially flattened; those who have small nostrils directed forwards, have commonly no smell; the privation of the nose by disease or accident, causes an almost total loss of smell. According to the interesting observations of M. Beclard, this sense is re-produced in persons so situated, by supplying them with an artifical nose.

What is the use of the sinuses? That of furnishing a great part of the nasal mucus, is commonly received. Other uses attributed to them, viz. to serve as a deposi-

* This is the explanation given in the school of Paris: it is at first sight satisfactory; but, on close examination, it will be found to rest on several gratuitous suppositions, such as the affinity of odours to the nasal mucus, the deposition of odourous particles upon the pituitary membrane, &c.

tory for air loaded with odorous effluvia, to increase the extent of the smelling surface, and to receive a portion of air during inspiration for the purpose of exciting smell, are any thing but certain.

Vapours and gases seem to act upon the pituitary membrane like odours. The mechanism of their action, however, must be rather different. Bodies reduced to a pretty coarse powder, have also a strong action upon this membrane; their first action is painful, but custom at length converts the pain into a pleasure, as we see in the example of tobacco. This property of the pituitary membrane is taken advantage of in medicine to excite a strong instantaneous pain.

In the history of smell, we must not omit the use of the hairs of the nostrils and entrance to the nasal fossæ; they are perhaps intended to prevent foreign bodies, diffused in the air, from reaching the nasal fossæ. They will thus be very analogous in function to the eye-lashes and the hairs of the auditory canal.

The olfactory nerve is universally regarded as especially destined to transmit to the brain the impression produced by odorous bodies; but there is no positive proof that the other nerves which run to or near this membrane, do not contribute to this function.

Modifications of Smell by Age.

The olfactory apparatus is but little developed at birth; the nasal cavities, and the different cornets scarcely exist; the sinuses do not exist, and yet smell seems to take place. I think I have observed that infants, a short time after their birth, smelt the nourishment which was presented to them. With the progress of age, the nasal cavities become developed and the sinuses formed, and it appears that in this respect smell grows more perfect till old age. Smell continues to the last moment of life, unless particular lesions of the apparatus, such as modifications in the secretion of mucus, which are very frequent, take place.

Smell is intended to inform us of the composition of bodies, and especially of our food; generally speaking, bodies of a disagreeable odour afford nourishment not very good, and often even dangerous. Many animals seem to possess more acute smell than ourselves. This sense is besides the source of a number of agreeable sensations, which have a remarkable influence upon the state of mind.

TASTE.

Of Savours.

Savours are only the impression of certain bodies upon the organs of taste. The bodies which produce them are called *sapid.*

It has been supposed that the degree of sapidity might be judged of by the solubility of a body; but some insoluble substances have a very marked taste, and some very soluble substances have scarcely any. Sapidity appears connected with the chemical nature of bodies, and the kind of effect which they produce upon the animal economy.

Savours are very various and numerous. Attempts have been made at different times to class them, but not with complete success; savours, however, are a little better understood than odours, no doubt because the impressions received by the sense of taste are less fugitive than those by that of smell. Thus we are well understood when we say a substance has an acrid, acid, bitter, austere, sweet taste, &c.

One distinction of savours is universally agreed upon, because it depends upon organization; it is that of agreeable and disagreeable tastes. Animals establish it instinctively.

This, too, is the most important distinction, for bodies of agreeable taste are usually good nourishment, while those of disagreeable, are usually injurious.

Apparatus of Taste.

The tongue is the chief organ of taste; the lips, however, inside of the cheeks, palate, teeth, velum pendulum, palate, pharynx, œsophagus, and stomach itself, are susceptible of impresssions by sapid bodies. The salivary glands, whose excretory ducts open into the mouth, and the follicles which there form the mucus which they secrete, contribute powerfully to the exercise of taste. Independently of the mucous follicles on the upper surface of the tongue, forming the *fungous papillæ,* we remark also little prominences, some very numerous, and called *villous papillæ,* and others, less numerous, disposed in rows on the sides of the tongue, and called *conical papillæ.*

All the nerves which run to the parts destined to receive the impressions of sapid bodies, ought to be comprehended in the apparatus of taste. Thus the inferior maxillary nerve, many branches of the superior, among which must be enumerated the branches which arise from the spheno-palatine ganglion, particularly the naso-palatine nerve of Scarpa, the ninth pair, the glosso-pharyngeal, &c. appear conducive to taste.

The lingual nerve of the fifth pair is commonly regarded by anatomists as the chief nerve of taste, for its branches are said to be prolonged into the villous and conical papillæ of the tongue. I have in vain attempted to pursue them so far: I have employed very delicate instruments, lenses, and microscopes improved on Dr. Wollaston's principles, but all my efforts have been fruitless; they entirely vanish the moment they reach the outer membrane of the tongue. One does not succeed better with respect to the other nerves of this organ.

Mechanism of Taste.

For the occurrence of taste, the mucous membrane of its organs must be perfectly entire and covered with mucus, and the saliva must flow abundantly into the mouth; when it is *dry*, taste cannot take place. This fluid too must be unaltered; for if the mucus is thick and yellow, if the saliva is acid, bitter, &c. taste will be imperfect.

Some authors have asserted that the papillæ of the tongue really become erected during the occurrence of taste; I believe this assertion is altogether without foundation.

For instantaneous taste, it is sufficient that a body be in contact with the organs of taste; but if it is solid, it must, in most instances, be previously dissolved in the saliva: this is not necessary for liquids and gases.

A certain chemical action appears exerted by sapid bodies upon the mucous membrane of the mouth; this is seen evidently at least in regard to some, as vinegar, mineral acids, alkalis, many salts, &c. In these different cases the colour of the epidermis changes, becomes sometimes white, sometimes yellow, &c. The same causes produce analogous effects on the dead body.

The greater or less promptness and permanency of the impression of different sapid bodies, probably depend upon the mode of this combination.

The strong influence of some bodies upon the teeth, have not yet been explained. The researches of M. Miel, a distinguished dentist of Paris, appear to show that it arises from imbibition: they seem to prove that the teeth readily imbibe liquids in contact with them.

The different parts of the mouth and fauces appear to have a particular mode of sensibility to sapid bodies; for these act sometimes in preference upon the tongue, sometimes upon the teeth and gums; at other times, exclusively upon the palate, pharynx, &c.

Some substances leave a lasting taste in the mouth, particularly aromatics. This *arrière-goût* is perceived sometimes in all the mouth, sometimes in one particular part. Acrid bodies, for instance, leave an impression in the pharynx; acids, upon the lips and teeth: peppermint at once upon the mouth and pharynx.

A body must remain some time in the mouth for its savour to be ascertained; if it passes through this cavity rapidly, it produces scarcely any impression; hence we swallow bodies quickly which have a disagreeable taste; and, on the contrary, allow those to remain long in the mouth which have an agreeable one.

After tasting a substance of a strong, tenacious savour, as, for instance, a vegetable acid, we become insensible to the weaker savour of other bodies. This remark is applied in physic to prevent patients from experiencing the disagreeable taste of certain medicines.

We may perceive many tastes at once, and distinguish their different degrees of intensity, as is done by chemists, *gourmets*, and tasters of drinks. We sometimes arrive in this mode at a very exact acquaintance with the chemical nature of substances; but taste acquires this perfection by practice only, or, if you choose, in fact, by education.

Is the lingual nerve the essential nerve of taste? I know of no fact which can give it exclusively this use. The experiment related by M. Richerand does not appear to me to decide this question; and this also is the opinion of this learned professor.

Modifications of Taste by Age.

It is difficult to say whether taste exists in the fœtus; it is certain that the principal organ of it, together with the nerves belonging to this organ, is very much developed. There can be no doubt that this sense exists in the new-born child, as we may convince ourselves by putting a bitter or salt substance upon its tongue or lips. The impressions of taste appear very lively in infants; we know that in general they dislike all food which has rather a strong savour.

Taste continues to the most advanced age; it is true that it becomes weak, and that an old man requires food and drink of a pretty strong savour; but this accords with the wants of his organisation, which requires active excitants for the support of its expiring energies.

Taste presides over the choice of our aliments; it enables us to distinguish hurtful from wholesome substances. This sense gives us the most certain knowledge of the chemical composition of bodies.

OF TOUCH.

Touch is a sense which acquaints us with most properties of bodies; and from being thought less liable to error than the other senses, and from serving occasionally to dissipate the errors into which the other senses have led us, it has been regarded as the sense by *way of excellence*, the *first of the senses*; but we shall see, that the advantges ascribed to it by physiologists, and especially by metaphysicians, require much restriction.

Tact must be distinguished from touch. Tact is, with some few exceptions, generally diffused over our organs, and particularly upon the cutaneous and mucous surfaces. It exists in all animals, while touch is exercised by certain parts only, evidently destined for this purpose, and does not exist in all animals, and is nothing more than tact combined with muscular contraction, directed by the will.

Physical Properties of Bodies, which put the Touch in Action.

Almost every physical property of bodies is able to throw the organs of touch into action: the form, dimensions, various degrees of consistence, weight, temperature, changes of place, vibration, &c.; are circumstances accurately ascertained by touch.

The organs destined for touch do not alone perform this function; so that in this respect touch differs from many other senses. As, however, in most cases, the skin receives the tactile impressions produced by surrounding bodies, it is necessary to say something of its structure.

The skin forms the envelope of the body, and is confounded with the mucous membranes at the entrance of all the cavities; but it is incorrect to say, that these membranes are a continuation of it.

The skin consists chiefly of the *derm* or *chorion*, a fibrous layer, of various thickness according to the parts which it covers, and adhering to these parts, sometimes by cellular membrane more or less compact, and sometimes by fibrous bands. The chorion is almost always separated from the subjacent parts by a thicker or thinner layer, which is of use in the exercise of touch.

The external coat of the skin is covered by the epidermis, a solid matter, secreted by the skin. The epidermis ought not to be considered as a membrane; it is an homogeneous layer, adhering by its inner surface to the chorion, and pierced by an infinite number of little holes, some for the passage of the hairs, others, of the cutaneous transpiration, and at the same time subservient to the absorption which occurs in the skin. The latter are denominated *the pores of the skin.*

We must observe, relatively to the epidermis, that it is insensible, possesses no vital properties, is not subject to putrefaction, wears away, and is repaired continually, and increases and diminishes in thickness according to necessity; it is also said to be out of the reach of the influence of the digestive organs.

The connection of the epidermis with the chorion is intimate, but nevertheless there can be no doubt of the existence between these two parts of a peculiar layer, in which some important phenomena go on. The organisation of this layer is but little understood. Malpighi thought it was formed of a peculiar mucus, whose existence has been long admitted, and which bears the name of *corpus mucosum of Malpighi.* Other authors have with more reason considered it as a vascular net-work;* M. Gall compares it to the grey matter observable in many parts of the brain.

* On the external surface of the chorion we distinctly see, in dead bodies, very numerous vessels, very fine, and full of blood, in the parts where blisters have been applied some time before death.

M. Gautier, when examining the external surface of the chorion with attention, remarked in it little red prominences disposed in pairs; they are readily perceived when the chorion is exposed by the action of a blister. These little bodies are regularly arranged on the palm of the hand and the sole of the foot. They are sensible, and reproduced when removed. They appear essentially vascular: they have been long called, without attentive examination, the *papillæ of the skin.* Opposite their summit, the epidermis is pierced by a small opening, from which small drops of sweat escape when the skin is exposed to rather an elevated temperature. The skin contains a number of sebaceous follicles; and receives many vessels and a very large number of nerves, particularly at those parts of the membrane which serve for touch. We are completely ignorant of the mode in which the nerves terminate in the skin; all that has been said of the cutaneous nervous papillæ is purely hypothetical.

The exercise of tact or touch is favoured by the thinness of the chorion, a rather high temperature of the atmosphere, an abundant cutaneous transpiration, and by a certain degree of thickness and suppleness of the epidermis. When the contrary dispositions exist, tact and touch are always more or less imperfect.

Mechanism of Touch.

The mechanism of touch is extremely simple: it is sufficient that bodies be in contact with the skin, for us immediately to acquire more or less accurate information of the tactile properties of bodies.

Touch enables us to judge particularly of temperature. When bodies take caloric from us, we call them cold; when they give it to us, we call them hot; and according to the quantity of caloric which they give to us or take from us, we determine their different degrees of heat or coldness. Our opinions, however, respecting temperature, are far from corresponding strictly with the quantity of caloric bestowed upon or taken from us. We unconsciously combine with them a comparison with the state of the atmosphere, so that a body colder than our own, but warmer than the atmosphere, will appear warm, although in reality it deprives us of caloric when we touch it. For this reason, places of an uniform temperature, as caves and wells, appear cold in summer and warm in winter. The capacities of bodies for caloric also influences our opinions respecting temperature, as is proved by the different sensations produced by iron and wood, although of the same temperature. A body sufficiently heated, chemically to decompose our organs, causes the sensation of *burning*. A body, whose temperature is sufficiently low quickly to absorb a large portion of caloric from a part, produces an analogous sensation, as we may be convinced by touching frozen mercury.

Bodies which exert a chemical action upon the epidermis, which dissolve, as caustic alkalis and concentrated acids, cause a sensation easily known, and which may serve to distinguish these bodies.

Every point of the skin is not endowed with the same degree of sensibility, so that the same body applied successively to different points of the cutaneous surface, will produce a series of different impressions.

The mucous membranes enjoy a very delicate tact. Who is ignorant of the great sensibility of the lips, the tongue, conjunctiva, pituitary membrane, mucous membrane of the trachea, ureter, vagina, &c. The first contact of bodies not naturally intended to touch these membranes, is at first painful, but this effect is soon changed by habit.

In man, the hand is the chief organ of touch; all the most advantageous circumstances are combined in it. Its epidermis is fine, polished, and very supple, the transpiration and oily secretion abundant. The vascular prominences are more abundant there than any where else. Its chorion is not too thick; it receives a number of vessels and nerves; it adheres to the subjacent aponeuroses by fibrous bands, and is supported by a fatty and very elastic cellular tissue. It is at the extremity or pulp of the fingers that all these dispositions are in the highest perfection; the motions of the hand are easy, very multiplied, such, in short, that this part can apply itself to all bodies whatever may be the irregularity of their figures.

As long as the hand remains motionless on the surface of a body, it acts only as an organ of tact. To exercise touch, it must move, either to run over their surface, for the purpose of informing us of their form, dimensions, &c. or to compress them, that we may ascertain their consistence, elasticity, &c.

When a body is of considerable dimensions, we employ the whole hand to touch it; if, on the contrary, the body is very small, we touch it with the extremities of the fingers. The power possessed by man of opposing the pulps of the fingers to each other, gives him a great superiority over animals in this respect. His touch is so perfect, that it has been called the source of his intelligence.

From the remotest antiquity, touch has been much extolled beyond the other senses; it has been considered the cause of human reason. This idea has continued to the present day, and has been remarkably extended in the writings of Condillac, Buffon, and modern physiologists. Buffon, in particular, ascribed such importance to touch, that he believed one man had not much more sense than another, except from having employed his hands more promptly and extensively from his infancy. It would be well (said he) to give children the free use of their hands from the moment of their birth.

Touch has really no prerogative over the other senses; and if in some cases it assists the action of the eye and ear, these senses are in others of great assistance to it, and there is no reason to believe that the ideas which it excites in the brain are of a more elevated order than those which are excited by the action of the other senses.

Modifications of Tact and Touch by Age.

Does the fœtus enjoy tact and touch? The negative is probable, at least if we understand these words in their strictest signification. It is said that the first contact of air with the skin of the child at birth produces a lively pain which excites its cries. This opinion I think slightly founded.

Tact and touch deteriorate with age. In the old man they are sensibly altered; but at this age the skin has undergone disadvantageous changes: the epidermis is no longer so supple, transpiration proceeds imperfectly, the fat having disappeared which before supported the chorion, this wrinkles and becomes flabby. We must conceive that all these causes must injure the exercise of tact and touch, especially when we know that the power of feeling itself has experienced a considerable diminution in the old man.

Touch may arrive at a very high degree of perfection by exercise, as we observe in many professions. A very well practised touch is indispensable to a surgeon, and even to a physician.

Of the Internal Sensations.

Every organ possesses, like the skin, the faculty of transmitting impressions to the brain when touched by external bodies, or when merely intermediately compressed or rubbed, &c. We may say that they possess tact in general.

The bones, however, tendons, aponeuroses, ligaments, &c. must be excepted, which in the healthy state are insensible, and may be cut, burnt, torn, &c. without the brain perceiving it.

This important fact was not known by the ancients; they considered all white parts as nervous, and ascribed properties to them which we now know belong only to nerves. We owe to the experiments of Haller and his disciples this useful result, which has had great influence upon the modern progress of surgery.

Without the intervention of any external cause, every organ may transmit different impressions to the brain. They are of three kinds. The first occur when it is necessary for organs to act; they are called *wants, instinctive desires:* such are hunger, thirst, the want to make water, or to respire, venereal appetites, &c.

The second takes place during the action of the organs; they are often obscure, but sometimes very lively. Of this number are the impressions which accompany the different excretions, as that of the semen and of the urine. Such are likewise the impressions which inform us of our movements, and of the periods of digestion : thought itself may be referred to this kind of impression.

The third kind of internal sensations are developed when the organs have acted. To this kind belongs the feeling of fatigue, which varies in the different apparatus of the functions.

To these three kinds of impressions must be added those which are felt in disease : these are infinitely numerous, the profound study of them is indispensable to the physician.

All sensations coming from within, arising independently of external agents, have been collectively designated by the denomination of *internal sensations*, or *sentiments*.

Their consideration was neglected by the metaphysicians of the last age ; but this has now become the object of the study of many distinguished authors, particularly of Cabanis, and M. Destutt-Tracy, and their history is one of the most curious parts of ideology.

Of the pretended sixth Sense.

Buffon, when speaking of the liveliness of the agreeable sensations produced by the approach of the sexes, said figuratively, that it depended upon a sixth sense.

Magnetisers, and especially those of Germany, talk much of a sense which is present in all the rest ; which is awake while they are asleep, and which is particularly developed in somnambulists, to whom it gives the power of predicting events. This sense forms the instinct of animals, and forewarns them of approaching dangers. It resides in the bones, viscera, ganglions, and nervous plexuses. To answer such reveries would be loss of time.

M. Jacobson having discovered a peculiar organ in the os incisivum of animals, suspected that it might be the source of a distinct order of sensations, but gives no proof of his opinion.

Lastly, the faculty possessed by bats of directing their flight in the darkest places, induce Spallanzani and M. Jurine of Geneva to think those animals were endowed with a sixth sense; but M. Cuvier has shewn that this faculty depends upon the sense of touch.

There is, therefore, no sixth sense.

OF THE SENSATIONS IN GENERAL.*

The sensations constitute the first part of the life of relation: they establish our passive relations with surrounding bodies and with ourselves. This expression of passive is, or may be readily supposed to be, true in a certain sense only; for the sensations, like the other functions of the economy, are the result of the action of the organs, and consequently in fact active.

Every thing which exists is capable of acting upon our senses; we are positively informed of the existence of bodies by this means only. Sometimes bodies act upon our organs directly, sometimes by the intervention of other substances, as light, odours, &c.

Most bodies can act upon several of our senses; others, on the contrary, influence one only.

The apparatus of the sensations, or the senses, are formed of an external part endowed with physical properties in relation with those of the substances, and of nerves which receive the impressions, and transmit them to the brain.

The external part of the apparatus of vision and of hear-

* General considerations being founded upon particular facts, we shall place them after the exposition of the latter: this course is conformable to the mechanism of the formation of ideas.

ing is very complicated; in the other senses, it is very simple; but in all, the relation between their physical properties and the substances are such, that the least alteration of these properties creates a marked disturbance in the function.

Of the Nerves.

The nerves which form the second part of the apparatus of sensation, are organs essential to sense.

All the nerves have two extremities; one confounded with the substance of the brain: they are disposed differently in different organs. These two extremities have been in turn called the origin or the termination of the nerves. Some say that all the nerves arise from the brain and terminate in the organs; others, on the contrary, that they arise from the organs, and by their general union form the brain. These expressions are incorrect and give a false idea; they can be useful in the description only of organs; and as others might be substituted for them without any obscurity, perhaps it is desirable that they should be abandoned: for it is evident that the nerves *no more form the brain by their union, than the brain gives origin to the nerves.* By these terms, the disposition of the two extremities of nerves is expressed metaphorically.

The cerebral *extremity* of nerves presents extremely fine and soft filaments, which are continued into the substance of the brain, at a little distance from the point where they are first seen. These filaments reunite and form the nerve.

There are marked differences among the nerves; some are rounded, some flattened, some, as it were, channelled on their sides; some very long; some very short. It may be said that no two nerves are completely alike in form, colour, &c. They are generally placed in such a way as to be seldom exposed to external injuries.

While running towards different parts, the nerves divide into branches and twigs, and ultimately, in the substance of organs, into filaments so fine that they are no longer visible but by the aid of optical instruments. Nerves communicate with one another, anastomose, and form what are called plexuses.

With the exception of the optic nerve, whose *organic* extremity is easily seen, and of the acoustic, of which we have some knowledge, the disposition of the extremities of the nervous filaments in the substance of organs, is altogether unknown. Much has been said of the extremities or nervous pulps, and even physiological explanations have been given of them; but all this is purely imaginary. The bodies which have been and even now are called *nervous papillæ* may be readily shewn to have no existence.

The nerves are in general formed of extremely fine filaments, which might probably be reduced into still finer, if our means of division were more perfect. These filaments which have been called *nervous fibres*, have frequent communications, and in the body of nerves affect a disposition, which is, on a small scale, the same as that of the plexuses. Each fibre is usually believed to be formed of an envelope (*neurilema*) and a central pulp, similar in its nature to the cerebral substance. What has been said on this point I consider hypothetical. I have made the greatest efforts to repeat the preparations recommended by anatomists for seeing this structure, but with all my care, have never been able to discover it. When we can hardly even with a microscope discover the fibre itself, and may very reasonably suppose it formed by the union of more delicate fibres, how is it possible to distinguish a cavity in it filled with pulp?

Whatever may be the physical disposition of the substance forming the nervous parenchyma, we are certain that it has the same chemical properties as the cerebral substance, and that each nerve receives small arteries which are numerous in proportion to its volume, and presents a proportional number of venous radicles.

The posterior branch of all the nerves *arising* from the spinal marrow, presents not far from the point of union with the anterior branch, a tumefaction called a *ganglion.* These bodies, very different in colour, consistence, and structure from nerves, have no ascertained use. The nerve of the eighth pair immediately at its departure from the cranium, frequently presents an enlargement of this kind.

Of the Mechanism, or physiological Explanations of the Sensations.

The physiological explanations of the sensations consist of the more or less exact application of the laws of physics, chemistry, &c. to the physical properties of the apparatus placed before the nerves, as we remarked in the particular history of each sensation. As soon as we arrive at the uses of the nerves in these functions no further explanation can be given, we must strictly limit ourselves to the observation of facts.

This inference, so readily deduced, has been seen but by few authors, and in their works is even expressed but vaguely. At all times explanations of this action of nerves have been attempted. The ancients considered the nerves as the conductors of the animal spirits; when physiology was governed by mechanical ideas, the nerves were considered as vibrating chords, without its being recollected that they have no qualities necessary for vibration. Some men of merit have imagined that the nerves conducted and even secreted a subtle fluid which they denominated *nervous;* according to them, sensations are transmitted to the brain by means of this fluid. At present, when our attention is being directed towards the study of imponderable fluids, this opinion has a number of advocates. I am acquainted with some learned men who do honour to the age by their talents, and who are very much disposed to believe that electricity has much influence in our sensations and the other functions. To attempt explaining sensations by referring them to a vital principle, called *animal, perceptive, relative,* is having recourse to the most defective kind of explanation: for the expression only is changed, and the difficulty remains unaltered.

Without anticipating any thing, we range the action of the nerves among the vital actions, which, as we saw at the beginning of this work, are not susceptible of any explanation in the present state of science.

But is it certain that the nerves transmit the impressions received by the senses? This is positively demonstrated by observation and experiment.

If a man receives a wound in a nervous trunk, the part to which this nerve is distributed, becomes insensible. If the optic nerve suffers, blindness ensues; if the auditory, deafness.

These effects are produced on animals at pleasure, by cutting or merely tying or compressing the nerves. When the ligature is removed, or the compression taken off, the part recovers its former sensibility.

The wound of a nerve produces horrid pain in man as well as in animals; indeed every disease which even slightly alters the structure of nerves, manifestly injures their power of transmission.

We know nothing of the use of the numerous anastomoses which occur among nerves; the suppositions which have been devised to explain their use, only show that physiology is in its infancy.

Sensations are lively or weak. The first time that a body acts upon our senses, it generally produces a strong impression. Its strength, however, diminishes if the action of the substance is repeated, and it may in this way nearly altogether cease. This fact is expressed by saying that *habit deadens feeling*. As the intensity of existence is measured by the liveliness of sensations, man endeavours continually to procure new ones, which are always more lively: hence his inconstancy, his restlessness and ennui, if he remains exposed to the same causes of sensations. We are able to render our sensations more lively and accurate. For this purpose, we dispose the sensitive apparatus in the most advantageous manner, we receive a small number only of sensations at once, and direct all our attention to them: thus an import difference is established between *seeing* and *looking*, *hearing* and *listening*. The same difference exists between the *common exercise of smell* and *the action of smelling to*; between *tasting* and the action *de déguster*; between *touching* and *feeling*.

Nature has given us the power also of increasing the strength of our sensations. Thus we contract the eyebrows, we approximate the eyelids, when the impression of light is too strong; we breathe by the mouth when we wish to avoid the action of too strong an odour, &c.

Moreover, the sensations direct, clear, modify, and even denaturalize one another. Smell appears the guide and sentinel of taste; taste, in its turn, has a powerful influence upon smell. Smell can insulate its functions from those of taste; what pleases the one, does not always equally please the other; but as food and drink cannot easily pass through the mouth without acting more or less upon the nose, as often as they are disagreeable to the taste, they soon become so to the smell, and those to which the nose first shewed a strong repugnance, at length overcome its repugnance when forcibly desired by the taste.*

Numerous observations prove, that the liveliness of impressions received by the senses, is increased by the loss of one of these organs. For instance, smell is more acute in the blind or deaf than in others who have all their senses. I think, however, that I have remarked, that the absence of a smell, which is a very frequent occurrence, does not add acuteness to the other senses.

The sensations are *agreeable* or *disagreeable:* the former, especially when acute, form *pleasures;* the latter, *pain.* By pain and pleasure, nature leads us to harmonize with the order established among organised beings.

Although we cannot say, without committing a sophism, that pain is merely a shade of pleasure; it is, however, certain that persons who have exhausted all the sources of enjoyment, and are thus become insensible to all the ordinary causes of sensations, seek for causes of pain, and are pleased with their effects.

Do we not see in great cities men surfeited and degraded by debauchery, finding agreeable sensations in what would give others intolerable pain?

It is necessary to remark that the sensations which proceed from the senses are in general accurate and distinct:

* Cabanis.

all the ideas and knowledge that we have of nature result from them particularly.

The sensations which arise within, or the feelings, do not present these characters. They are generally confused, vague, often indeed unnoticed; they do not impress the mind, but are always more or less fugitive.

If our organs act freely, and according to the common laws of organisation, the feelings which result from them are agreeable, and may even produce a very lively pleasure; but if our functions are troubled, our organs wounded, diseased, or impeded in their action, the internal sensations are painful, and have a peculiar character according to the description of the impediment or lesion. Hence pain is an important object of study to the physician.

Are the nerves which run directly to the brain or spinal marrow the organs of the transmission of the internal sensations? This is probable; physiologists of the present day, however, ascribe a great share of this function to what they call the *great sympathetic nerve*.* They are

* Why should the great sympathetic be viewed as a nerve. The ganglions and filaments which proceed from it, or go to it, have no analogy with nerves properly so called; colour, form, consistence, disposition, structure, properties of tissue, chemical properties, every thing is different. The analogy in the vital properties is not more marked: a ganglion may be pricked, cut, or even torn out, without the animal perceiving it. I have frequently made such experiments in the ganglions situated in the neck of dogs and horses: similar operations upon the cerebral nerves produce dreadful pain. If the ganglia of the neck, or even the thoracic ganglia are removed, no sensible derangement of the functions ensues, even in the parts where the filaments which spring from them may be traced. Why then should the system of ganglions be considered as a part of the nervous systém? Would it not be wiser and more advantageous to the future progress of physiology to allow that the uses of the grand sympathetic are at present completely unknown? This view is much confirmed by reading authors; each has his own

perhaps right; but it is impossible to receive this opinion, for it is founded upon no positive fact or experiment.

These causes which modify the external or internal sensations are innumerable; age, sex, temperament, season, climate, habit, individual disposition, are circumstances which taken separately would be sufficient to produce numerous modifications in the sensations; hence, *a fortiori*, when united, they must have a more manifest effect: the difference of the sensations in each individual is expressed in common language by this phrase, *Each his way of being or feeling.*

In the fœtus there are probably only internal sensations: this at least we are led to suppose from its motions, which seem to result from impressions arising spontaneously in organs. Direct experiment shows that derangements in the circulation or respiration of the mother are followed by very marked motions of the fœtus.

All the sensations do not exist at birth, and some time afterwards. Taste, touch, and smell are alone employed; sight and hearing are developed later, as we have mentioned in the particular history of these functions.

Each sense passes through different degrees before arriving at that in which it is exercised perfectly: it must really and indispensably go through an education. If we follow the sensations through their developement, as metaphysicians have done, we may easily observe the modifications which it experiences while arriving at perfection.

opinion. They are taken for nervous centres, little brains, nuclei of grey matter destined to nourish the nerves, &c. If proofs of any of these doctrines are required, we are surprised at finding none, and discovering the writer's assertion to be a mere *jeu désprit.*

The education of those sensations which occur at a distance is more slow and difficult; those which occur in contact appear to take place more easily. During this education, i. e. during the first part of infancy, the sensations are confused and weak; but those which succeed them, and especially those of young persons, are remarkable for liveliness and multiplicity: at this age they are deeply impressed upon the memory, and consequently destined to form part of our intellectual existence during the whole of our life.

The sensations lose their liveliness with age; but they become perfect with respect to accuracy, as we see in adults. In the old man they become weak, and are produced with slowness and difficulty.

This effect is more striking in those senses which acquaint us with the physical properties of bodies, and less so in those which bring us into relation with chemical properties.

The latter senses (taste and smell) are the only ones which preserve any activity in the age of decrepitude; the others are commonly nearly extinct, from the diminution of sensibility and the succession of physical alterations which they have experienced.

OF THE FUNCTIONS OF THE BRAIN.

The human intellect consists of phenomena so different from all others in nature, that they are referred to a particular being, regarded as an emanation from the Divinity.

The belief in this being is too consolatory for the physiologist to doubt its existence; but the strictness of language and logic at present observed in physiology requires the human intellect to be treated as the result of the action of an organ. By deviating from this course, justly celebrated men have fallen into great errors; and by pursuing it, we have, moreover, the great advantage of observing the same method of study, and of rendering some things easy which are commonly supposed almost above the human intellect.

Of the Brain.

The brain is the material organ of thought: this is proved by a number of facts and experiments.

Under the term *brain*, I comprehend three parts distinct from each other, although united in some points. Those parts are the *cerebrum*, *cerebellum*, and *spinal marrow*.

In each of these principal divisions we find also other parts, easily distinguishable, and which have a kind of insulated existence, so that nothing is more complicated, nothing more difficult in anatomy, than the study of the organisation of the brain. In proportion, however, to the importance of the functions of this organ, anatomists and physicians have in all ages applied themselves to dissect it. Hence the anatomical description of the brain is one of the most perfect parts of anatomy. Very recently this subject has had new light thrown upon it by the publication of the work of Drs. Gall and Spurzheim, and by the labours to which it has given rise.

As the brain is of an extremely delicate texture, and its functions impeded by the slightest physical derangement, nature has been very careful to defend it from the injurious effects of all surrounding bodies.

Among the protecting parts of the brain, which may be called the *tutamina cerebri*, must be mentioned the hairs, the skin, the muscles of the scalp, the pericranium, the cranial bones, and the dura mater, which are particularly destined for the protection of the cerebrum and cerebellum.

By their number and disposition, the hairs are calculated to destroy shocks given to the head, and to prevent too strong a pressure from injuring the skin of the cranium. Being bad conductors of caloric, their assemblage forms a sort of tissue or wadding, the plates of which intercept a great number of little masses of air, so that they are well calculated to preserve the head of one uniform temperature in some measure independent of that of the atmosphere and surrounding bodies: besides, as they are impregnated with an oily matter, they imbibe but a small quantity of water, and readily dry.

The hairs are bad conductors of electricity, and in some degree insulate the head; whence the brain is less strikingly influenced by electricity. It is easy to conceive how the skin of the head, the subjacent muscles, and the pericranium, concur in protecting the brain: there is no necessity to insist on this point.

But of all the means of protection to the brain, the most efficacious is the covering afforded it by the bones of the cranium. In proportion to the hardness and spheroid disposition of this covering, all pressure or percussion of the head is reflected from the point which is compressed or struck, towards all the others, and less directed to the brain. A man for instance receives a blow by a stick upon the top of his head: the motion is propagated in every direction, as far as the middle of the base of the cranium, i. e. as far as the body of the sphenoid bone. If the stick had struck the forehead, the effort would have been propagated and concentrated towards the middle of the occipital bone.

In this transmission of motion communicated to the cranium, the bones have been thought to experience a slight reciprocal displacement, not very evident on account of the disposition of the different articulations; but there is reason to believe that the cranium resists as if it were composed of one piece.

A fact not sufficiently attended to, is that the cranium must necessarily change its form as often as it is pressed or struck rather forcibly. The softness of the cerebral mass allows it to bear slight changes of its covering without any ill effect. The softer the brain, the stronger pressure or percussion will it be able to endure without inconvenience; hence, children at birth, when the bones of their heads have very free motion upon each other, suffer compression and even sensible deformity of them, without any pernicious result. It is the same with older children, who receive violent blows upon their head with impunity. At this age, and especially at birth, the brain is much softer than in the adult.*

The dura mater is in some degree disposed to protect the brain against itself. For without the falx and the tentorium, the hemisphere of one side would ponderate against the other when the head is inclined; the brain would compress the cerebellum when the head is erect; so that the different parts of the brain would injure each other's functions.

* If the brain was perfectly fluid and homogeneous, whatever might be the extent of the changes of form of its covering, no injurious effect would result; but as the brain is of a soft consistence, and not perfectly homogeneous, violent blows are often followed by dangerous consequences, as concussion, extravasations, abscesses, &c.

If the precautions taken by nature to preserve the cerebrum and cerebellum from external injury, are compared with those which surround the spinal marrow, we shall presume that the latter part is still more important than the former, or at least, that its texture, being more delicate, requires more multiplied care; this, in truth, is the case. The office of the spinal marrow in the economy, is at least as important as that of the cephalic portion of the nervous system. The least percussion injures it, the least compression suddenly destroys its functions: it was therefore necessary for the vertebral canal which contains it to afford it a good protection. The end is so completely attained, that nothing is more rare than a lesion of the spinal marrow. It was necessary for the vertebral canal to unite great mobility to the requisite degree of solidity: it is the general termination of all the efforts which the body makes and which are made upon it; it is the centre of all the motions of the limbs; and even executes very extensive motions.

We cannot enter into the details of this admirable mechanism: Bichat's *Traite d'Anatomie Descriptive*, t. 1. p. 161, et seq. may be read on this subject.

Besides the coverings of the brain already mentioned and the dura mater which covers it through its whole extent, this organ is surrounded on all sides by a very fine serous membrane (the *arachnoid),* the chief use of which is to furnish continually a rare fluid which lubrifies the brain. The arachnoid penetrates into the cavities of the brain, and even there furnishes a perspiratory fluid.

The mode in which the blood vessels run to and from the brain, is extremely curious; we shall treat of it under the article *circulation.* We shall at present confine ourselves to remarking that the arteries, before penetrating the cerebral substance, are reduced to capillaries; that the veins affect the same disposition on leaving this substance; and as these very delicate vessels communicate by numerous anastomoses, a vascular network is formed upon the substance of the brain, improperly termed *membrana pia mater*. This network insinuates itself into the substance of the brain; it is that which, in the ventricles, constitutes the *plexus choroides* and *choridian web*.

We shall not give an anatomical description of the brain, but shall confine ourselves to some general reflections.

A. Almost all authors who have given an anatomical description of the brain, have not been sufficiently strict in their expressions, and have been prejudiced by some hypothesis. It is indispensable to the future progress of anatomy and physiology, to employ none but precise terms, to avoid metaphorical expressions as much as possible, and, above all, to reject the supposition that all the nerves terminate or meet in a certain point of the brain; that the soul is seated in some part of this organ; that the nervous fluid is secreted by a portion of the cerebral mass, while the rest serves to conduct this fluid, &c. From not having followed this method, authors who have described the brain, have given false ideas and expressed themselves obscurely.

B. By brain we must understand the organ which fills the cavity of the cranium and of the vertebral canal. For the facility of study, anatomists have divided it into three parts, the brain properly so called *(cerebrum)*, the *cerebellum*, and the *spinal marrow*. This division is purely scholastic. These three parts in truth form but one and the same organ. The spinal marrow is no more a *pro-*

longation of the cerebrum and cerebellum, than these are an expansion of the spinal marrow.

C. To say that the grey substance of the brain produces the white, is advancing a gratuitous supposition, while the grey matter no more produces the white, than a muscle produces the tendon which terminates it; than the heart produces the aorta, &c. In this point of view, the system of Drs. Gall and Spurzheim is essentially false.

D. Of all animals, man has the largest brain, properly so called, in proportion. The dimensions of this organ are proportional to those of the head. In this respect, men differ from each other. In general the volume of the brain is in direct relation with the mental capacity. It would, however, be wrong to believe that every man with a large head must necessarily possess a superior intellect; for many causes independently of the volume of the brain, may increase the volume of the head; but a man with a small head is rarely distinguished for his mental faculties. The only method of estimating the volume of the brain in a living person, is to measure the dimensions of his cranium: every other method, even that proposed by Camper, is erroneous.

E. The brain of man presents the most numerous *convolutions* and the deepest aufractuosities. The number, size, and disposition of the convolutions are various; in some brains they are very large, in others more numerous and small. Their disposition is different in every individual: those on the right are not disposed like those on the left. It would be curious to inquire if there is any relation between the number of the convolutions, and the perfection or imperfection of the intellectual faculties, between the modifications of the mind and the individual disposition of the cerebral convolutions.

F. The volume and weight of the cerebellum vary in different individuals, and especially according to age. In the adult, the weight of the cerebellum is one-eighth or ninth of that of the cerebrum: it constitutes a sixteenth or eighteenth only in the new-born child; no convolutions are found on its surface, but many strata of lamellæ, each separated by a furrow. The number and disposition of these lamellæ vary considerably in different individuals. The remark which we made when speaking of the cerebral convolutions may be repeated here. An Italian anatomist (Malacarne) said that he found but three hundred and eighty lamellæ in the cerebellum of a maniac, while in other individuals he discovered more than eight hundred.

The substance of the brain is soft and pulpy; readily spoils its shape spontaneously; in the fœtus is nearly fluid; more consistent in the child, and still more so in the adult. Its consistence varies in different parts and in different individuals. The brain has a nauseous spermatic odour, which is very tenacious, and continues many years in dried brains (Chaussier).

G. Two substances are distinguishable in the brain; one grey, the other white. The *white substance*, still called *medullary*, constitutes the greater part of the organ, and chiefly occupies the interior and the part corresponding with the base of the cranium; is firmer than the grey portion; has a fibrous appearance; and forms the chief part of the spinal marrow, but particularly its superficial layer.

The grey substance, still called *cineritious, cortical,* forms a coat of various thickness on the exterior of the cerebrum and cerebellum; grey matter is, however, found in their interior; sometimes it is covered by the white matter, sometimes it appears intimately mixed with it, or at least these two substances are disposed in alternate layers or striæ. If we confine ourselves to colour, many other substances may be distinguished in the brain, for we observe in it yellow parts, black, &c.*

When the substance of the brain is examined with a microscope, it appears composed of an immense number of globules of unequal thickness. They are said to be eight times smaller than those of the blood: in the medullary substance they are arranged in a straight line, and have the appearance of fibres; in the cineritious substance they are heaped confusedly together.

II. According to M. Vauquelin, there is no difference between the various parts of the nervous system: the analysis of the cerebrum, cerebellum, spinal marrow, and nerves, gave the same result. He found the same matter throughout: it is composed of

Water	80,00
White fatty matter	4,53
Red fatty matter	0,70
Osmazome	1,12
Albumen	7,00
Phosphorus	1,50
Sulphur and salts, such as Acid phosphate of potass, ——— lime, ——— magnesia	5,15

The arteries of the brain are large: they are four in

* Soemmering distinguishes four substances in the brain: white, grey, yellow, and black.

number, the two internal carotids, and the two vertebral; they affect a disposition upon which we shall dwell in the article *Arterial Circulation.*

We shall say merely at present, that they are placed chiefly at the lower part of the organ, that they form a circle there from the manner in which they anastomose, and that they are reduced to capillary vessels before they penetrate into the substance of the brain.

The brain alone is thought to receive an eighth part of the blood which issues from the heart; but this estimation is only an approximation, and the quantity of blood received by the brain varies according to a number of circumstances. We know by recent dissections that the cerebral arteries are accompanied by branches of the great sympathetic nerve. These branches are easily traced upon the principal divisions of these arteries. They probably accompany them to their ultimate divisions; but we are not to conclude from this disposition, which is common to all arteries, that the brain receives nerves. The filaments of the grand sympathetic have here, as elsewhere, evident connections with the arterial parietes alone.

The cerebral veins have likewise a particular disposition; they occupy the upper part of the organ, have no valves; terminate in canals situated between the laminæ of the dura mater, &c.; we shall recur to this point in the article *Venous Circulation.* Lymphatics have not yet been observed in the brain.

Observations made upon the Brain of Man and Animals when alive.

In new-born infants whose cranium is in part membranous, and in adults after wounds and diseases which have exposed the brain, we remark that it has two distinct motions. The first is evidently synchronous with the pulsation of the heart and arteries; the other is equally so with respiration, i. e. the organ seems to shrink to return within itself during inspiration, while it presents the opposite phenomenon during expiration; and accordingly as the motions of respiration are more or less extensive, those of the brain are more or less conspicuous. These two kinds of motion are readily seen in animals, and it is difficult to conceive how they can lately have been called in question. They are thought to be scarcely sensible when the cranium is entire, and to be necessary to the cerebral functions; but nothing is demonstrated on this point.

The cerebrum and cerebellum exactly fill the cavity of the cranium in the dead body; consequently, during life, when these parts receive a large quantity of blood, their vessels are distended by this fluid, and a very abundant vapour is continually formed either on their surface or in the ventricles; the cerebrum and cerebellum may be conceived to experience a very considerable pressure, which must vary in intensity according to the quantity of blood which penetrates into or leaves the brain.

As the spinal marrow does not accurately fill the vertebral canal, it cannot be compressed like the cerebrum and cerebellum, but the pia mater exerts an evident pressure upon it, so that it is nearly in the same condition with respect to pressure as the cerebrum and cerebellum.

This pressure appears indispensable to the functions of the organ. As often as it is suddenly diminished or augmented, the functions are suspended; if the diminution or augmentation are gradual, the celebral functions continue.

The offices of the brain in the animal economy are extremely important and multiplied. It is the organ of intellect; it furnishes the principal of all the means which we possess of influencing external bodies: it exercises an influence more or less marked upon all the phenomena of life; it establishes a constantly active relation among the different organs, or, in other words, it is the chief agent of sympathies. We shall here consider it only in the first respect.

Of the Intellect.

Whatever may be the number and diversity of the phenomena which belong to the human intellect, however different they may appear from all the other phenomena of life, and however evidently they may be dependent upon the soul, it is necessary to consider them as the result of the action of the brain, and not in any measure to distinguish them from other phenomena which depend upon organic action. In truth, the functions of the brain are absolutely subjected to the same general laws as the other functions; are developed and deteriorated with the progress of age; are modified by habit, sex, temperament, and individual disposition; are troubled, weakened or exalted in disease; perverted or destroyed by physical lesions of the brain; and lastly, like all other organic actions, are not susceptible of any explanation; and to study them, we must confine ourselves to observation and experiment, divesting ourselves of every hypothetical idea.

We must not believe that the study of the functions of the brain is infinitely more difficult than of the functions of other organs, and that it belongs exclusively to metaphysics. By strictly adhering to observation, and carefully avoiding all explanation and conjecture, this study becomes purely physiological, and perhaps is easier than the study of other functions, from the facility with which the phenomena are produced and observed.

However this may be, the study of the intellect does not at present form an essential part of physiology; a science is specially devoted to it, I mean *ideology*. Those who wish to acquire enlarged views of this interesting subject, must consult the works of Bacon, Locke, Condillac, Cabanis, and especially the excellent work of M. Destutt Tracy, entitled *Elemens d'Ideologie*. We shall at present confine ourselves to some of the fundamental principles of this science.

The innumerable phenomena which constitute the human intellect,* are only modifications of the faculty of feeling. If they are attentively examined, this truth will be easily acknowledged, which is fully set forth by modern metaphysicians.

Four principal modifications of the faculties of feeling are received:

1. *Sensibility*, or the action of the brain, by which we receive impressions from within or without;

2. *Memory*, or the faculty of reproducing impressions or sensations previously received;

3. The faculty of perceiving the relations between sensations, or the *judgment*;

4. The *desires* or *will*.

Of Sensibility.

What we have said of sensations in general, is altoge-

* The human intellect is also called mind, *moral*, faculties of the soul, intellectual faculties, cerebral functions, &c.

ther applicable to sensibility; for this reason we only remark here, that this faculty is exerted in two different manners. In the first, the phenomena occur without our knowledge; in the second, we are informed of them, are conscious of them, we *perceive* the sensation. It is not therefore, sufficient, that a body act upon one of our senses, for a nerve to transmit to the brain the impression which is there produced; it is not even sufficient, that this organ receive this impression; for sensation really to occur, the brain must perceive the impression received by it. An impression thus perceived forms what in ideology is termed a *perception* or *idea*.

These two modes of sensibility may be easily proved upon oneself. It is easy to see, for instance, that a number of bodies act continually upon our senses without our knowledge: this depends in a great measure on habit.

Sensibility varies infinitely: in some, it is rather obtuse; in others, it is extremely exalted; in general, a good organization lies between these two extremes.

In infancy and youth sensibility is lively; it remains rather less marked till after the adult period; in old age it is evidently diminished; lastly, the decrepit old man appears insensible to all the ordinary causes of sensation.

Of Memory.

The brain can not only perceive sensations, but even reproduce those which it has perceived. This cerebral action is called *memory*, when it reproduces ideas lately acquired; and remembrance (souvenir), when the ideas are of earlier date.

An old man who recollects the ideas of his youth, has remembrance; a man who retraces sensations experienced the preceding year, has memory.

Reminiscence is an idea reproduced, which is not recollected to have occurred previously.

Memory is, like sensibility, very much developed in youth: during this period we acquire the most multiplied knowledge, but especially that which does not require much reflection, such as languages, history, descriptive sciences, &c. Memory grows weaker with the progress of age: it diminishes in the adult, and is almost entirely lost in the old man. Individuals, however, are seen in possession of a faithful memory at a very advanced age; but if this advantage does not depend upon great exercise, as in actors, it frequently exists only to the detriment of the other intellectual faculties.

The more lively the sensations are, the more readily are they recalled. The memory of internal sensations is almost always confused; some diseases of the brain completely destroy memory.

Of Judgment.

The most important of the intellectual faculties is indisputably judgment. By this faculty we acquire all our knowledge; without it, our life would be purely vegetative, we should have no idea of the existence of bodies nor of our own, for these two kinds of notions are, like all our knowledge, the immediate consequence of our faculty of judging.

To form a judgment, is to establish a relation between two ideas, or between two sets of ideas. When I judge that a work is good, I feel that the idea of goodness accords with the book which I have read; I establish a relation, I form an idea of a different kind from that which springs from sensibility and memory.

A series of judgments in connection form a *reasoning.*

The necessity of forming correct judgments, i. e. of establishing relations only which really exist, is evident. If I judge a poisonous substance to be wholesome, I run into danger of my life; my false judgment would be injurious to me. It is the same with all others of this kind. Nearly all the moral misfortunes of mankind arise from errors of judgment; crimes, vice, ill conduct, arise from false judgments.

There is a science whose object is to teach us to reason justly, it is logic; but sound judgment, or good sense, incorrect judgment, or wrong sense, depend upon organisation. We cannot change ourselves in this respect, but remain as nature formed us.

Certain men have the valuable gift of discovering unperceived relations. If these are very important, if they are of great advantage to mankind, these men are said to have *genius;* if they are less useful, if they regard objects of less importance, these are men of fancy, of imagination.

Men differ chiefly in their manner of perceiving relations, or of judging.

Acuteness of sensation impairs the correctness of judgment; hence this faculty grows perfect with age.

Of Desire or Will.

The name of *will* is given to that modification of the faculty of feeling by which we experience desires. It is in general the consequence of our judgments; but, what is very remarkable, our happiness or misery is necessarily connected with it.

When we satisfy our desires, we are happy; if we do not, we are unhappy; it is therefore important to give such a direction to our desires, that we may be happy; we ought not, for example, to desire things out of our reach; we ought still more carefully to avoid hurtful things; for in this case we cannot avoid unhappiness, whether our desires are satisfied or not. *Morals* are a science whose object is to give the best possible direction to our desires.

Desires are usually confounded with the cerebral action which presides over the voluntary contraction of the muscles: I think it useful to distinguish them.

Such are the four principal shades of the faculty of feeling, otherwise named, *the simple faculties of the mind.* By their combination, by their re-action upon each other, they constitute the understanding of man and the more perfect kinds of animals, with this difference, that in the latter, they remain nearly in their simple state, while man derives from them another part, and thus enjoys the intellectual superiority which distinguishes him.

The faculty of generalising, which consists in creating signs to represent ideas, to think by means of these signs, and to form abstract ideas, is that which characterises the human understanding, and permits it to acquire that prodigious extension which we behold in civilised nations: but this faculty necessarily requires the state of society; the individual who has always been insulated, and has never even in his infancy had any connection with his race, of which we have several examples, would not be very different from animals, for he would remain limited to the four simple faculties of the mind. It is the same with individuals, who, owing to defective organisation, are destitute of the faculty of employing signs and of forming abstractions or general ideas: they remain all their lives in a truly brutal state, as we observe in *idiots*.

In general the physical circumstances in which a man is placed, have great influence upon the developement of his understanding. If he readily procures his subsistence, if he satisfies all the wants of his organisation, he will be in the most advantageous situation for cultivating his mind and giving free play to his mental faculties; this occurs in civilised countries. But if a man gains his subsistence and satisfies his other wants with difficulty, his understanding, constantly directed towards the same end, will remain in an imperfect state; this happens in hunting nations, in hordes of savages, the rustic slave, &c.

Of Instinct and Passions.

Nature does not abandon animals to themselves; each of them must perform a series of actions, whence results the wonderful assemblage which we behold among organised beings. To lead *animals* to contribute to it and punctually execute the acts which they have to perform, nature has given them *instinct*, i. e. tendencies, inclinations, wants, by means of which they are continually excited and even compelled to fulfil the intentions of nature.

Instinct may occur in two different modes, either with or without a knowledge of the end. The first is enlightened instinct; the second, blind or brutal: the one is particularly the property of man, the other belongs rather to animals.

In carefully examining the phenomena which depend upon instinct, we find that it has in every animal a twofold object: 1. the preservation of the individual; 2. the preservation of the species. Each animal contributes to these ends, in its own way, and according to its organisation: there are also as many different instincts as there are species; and as organisation varies in every individual, instinct presents individual differences which are sometimes very striking.

In man we observe two kinds of instinct; the one depending more obviously upon his organisation, his animal condition; he manifests it in every situation. This kind of instinct is nearly the same as that of animals.

The other kind of instinct arises from the social state, it no doubt depends upon organisation; what vital phenomenon does not? But it is developed in proportion only as man lives in civilised society and enjoys the advantages of this state.

To the first, which may be called *animal instinct*, belong hunger, thirst, the want of clothing, that of an habitation, the desire of well-being, or of agreeable sensations, the fear of pain and death, the desire of injuring animals or one's kind, if the injury promises the prevention of danger, or the possession of advantage, venereal desires, affection for offspring, tendency to imitation and to living in society, which leads us through the different degrees of civilisation, &c. These different instinctive feelings are constantly leading man to contribute to the order established among organised beings. Man of all animals has the most numerous and various wants; a circumstance which corresponds with the extent of his understanding; had he these wants only, he would always enjoy a marked superiority over animals.

When man lives in society and easily satisfies all the wants which we have just mentioned, he has leisure, in other words, time and opportunity, to act more than his wants require; then it is that new wants arise which may be called *social;* such is that of possessing a lively feeling of existence, a want which, the more it is satisfied, becomes the more difficult to satisfy, because, as we have already said, sensations become blunted by habit.

This want of lively existence, added to the continuaally increasing weakness of sensations, produces a mechanical restlessness and vague desires, excited by the importunate recollection of the lively sensations which have been experienced: to get out of this state, the man is obliged to change his object continually, or to increase the same kind of sensations. From this springs an inconstancy which prevents our wishes from being limited, and a progression of our desires, which being always removed by enjoyment but iritated by recollection, become endless; hence the ennui which incessantly torments man when civilized and unoccupied.

The want of lively existence is balanced by the love of repose or idleness, which acts so powerfully upon the opulent class of society. These two contradictory feelings modify each other, and from their reciprocal action arises the love of power, of consideration, fortune, &c. which afford us all the means of satisfying both.

These two are not the only instinctive sentiments which arise in the social state; many others are developed, less important indeed, but not less real; the natural wants too become so altered as not to be recognised; hunger is often replaced by a capricious taste, venereal desires by a very different kind of feeling, &c. The natural wants influence the social, and these in their turn modify the former; when we also recollect that age, sex, temperament, &c. forcibly alter every kind of want, we shall be able to conceive the difficulty of studying human instinct: and in fact this point of physiology is at present scarcely even roughly sketched.

Let us however remark that the developemens of the social wants produces that of the understanding; there is nocomparison withrespect to intellectual capacity between a man of the higher class of society and one whose whole physical powers are scarcely sufficient for the satisfaction of his first wants.

Of the Passions.

By the word *passion* we generally mean an instinctive feeling become extreme and exclusive. The empassioned man neither sees nor hears, and exists only by the feeling which occupies him; and as the violence of this feeling is such that it becomes unpleasant and even painful, it has been termed *passion* or *suffering*.

The passions have the same objects as instinct; like it, they lead animals to act according to the general laws of animated nature.

In man we observe some passions common to him and animals, and consisting of increased social wants; but there are others which are developed in society only; these are the social wants greatly heightened.

The *animal passions* have reference to the two-fold object mentioned when we were speaking of natural instinct, i. e. to the preservation of the individual and of the species.

To the preservation of the individual belong fear, anger, sorrow, hatred, extreme hunger, &c.

To the preservation of the species, extreme venereal desires, jealousy, fury on seeing our offspring in danger, &c.

Nature has given great importance to these passions, which she reproduces in all their force in the civilized man.

The passions which belong to the social condition, are merely the social wants carried to a high degree. Ambition is the excess of the love of power; avarice, of the desire of fortune; hatred and vengeance, of injuring those who injure us; the passion for play, and nearly all vices, are likewise passions, violent wants of lively existence; violent love is an exaltation of venereal desires, &c.

Among the passions, some are appeased or extinguished when gratified, others irritated in proportion as they are gratified; and happiness is often the consequence of the first, as we observe in love and philanthropy, while misfortune is necessarily attached to the latter; of which the ambitious, the avaricious, the envious, are instances.

If wants develope the understanding, the passions are the principle or cause of all the greatness of human actions, whether good or bad. Great poets, heroes, great criminals and conquerors are empassioned men.

Shall we speak of the *seat* of the passions? Shall we say with Bichat that they reside in organic life? or with the ancients and some moderns, that anger resides in the head, courage in the heart, fear in the semilunar ganglion, &c.

But the passions are internal sensations; they can have no seat. They result from the action of the nervous system, and particularly from that of the brain: they therefore admit no explanation. We may observe, direct, calm, or extinguish them, but are not able to explain them.*

* This would be the place to treat of the use of the different parts of the brain, in the understanding and instinctive faculties; but this subject is too conjectural or too little known to be considered in an elementary work. We have been some time past engaged in experiments on this point, and shall lose no time in communicating the results when we judge them worthy of the attention of the public.

OF THE VOICE AND MOTIONS.

The functions already examined depend upon the faculty of feeling, by which we become acquainted with what surrounds us and with ourselves.

To complete the history of the functions of relation, we have to speak of those functions by means of which we act upon external bodies, impress upon them those changes which we judge necessary, and express our sentiments, our ideas to the beings among whom we live. These functions are but shades of one phenomenon, *muscular action*; so that the faculty of feeling on the one hand, and of muscular contraction on the other, really constitute our life of relation. We shall treat first of muscular contraction in general, after which we shall describe its two principal results, *voice* and *motion*.

Of Muscular Contraction.

Muscular contractility, what is called also *animal contractility, myotility, voluntary contractility*, &c. is not a vital property, at least in the true sense of this term; it results from the successive or simultaneous action of many organs; it must therefore be regarded as a function.

Apparatus of Muscular Contraction.

The organs which contribute to muscular contraction, are the *brain*, the *nerves*, and the *muscles*.

All attempts have hitherto failed to distinguish some parts of the brain, as exclusively destined for sensibility and understanding, and others for muscular contraction. It is in vain to propose to divide nerves into those of feeling and those of motion: this distinction is unfounded.

Hence we have nothing to add to what has been already said of the anatomy of the brain and nerves; we shall bestow a few words upon the muscles.

Of the Muscles.

The whole assemblage of muscles is called the *muscular system.*

The form, disposition, &c. of muscles vary infinitely. A muscle is formed by the union of a certain number of *muscular bands,* which are composed of still smaller bands; these again result from smaller ones, and thus by successive subdivision, we arrive at an extremely fine fibre, no longer divisible, but which would probably be susceptible of further division were our means more perfect. This fibre, indivisible to us, is the *muscular fibre;* it has been the object of many suppositions respecting its volume, form, and the disposition of its component particles. It is longer or shorter according to the muscles to which it belongs. Almost always straight, it does not divide, nor mix with other muscular fibres; it is surrounded by an extremely fine cellular tissue; soft and readily torn in the dead subject, it presents in the living body, on the contrary, a resistance which, when compared with its volume, is astonishing; it is composed essentially of fibrine and osmazome; it receives much blood, and at least one nervous filament. Some anatomists have endeavoured to explain the disposition of the vessels and nerves on arriving among the muscular fibres, but without saying any thing satisfactory. Every muscular fibre is attached by its two extremities to fibrous prolongations *(tendons, aponeuroses)* which conduct the power developed during its contraction.

Muscular contraction, such as it ordinarily occurs during life, supposes the free and ready exercise of the brain, the nerves which run to the muscles, and of the muscles themselves. Each of these organs must receive arterial blood, and the venous blood must not long remain in its substance. If one of these conditions fails, muscular contraction is impossible, perverted, or very much weakened.

Phenomena of Muscular Contraction.

When a muscle contracts, its fibres more or less suddenly shorten and become hard, and without any preparatory oscillation or hesitation; they suddenly acquire such a degree of elasticity, that they are enabled to vibrate or produce sounds. The colour of the muscle does not seem changed at the moment of its contraction; but it has a certain tendency to be displaced, which is resisted by the aponeuroses.

It has been disputed whether a muscle is more voluminous during its contraction or its relaxation: we do not think the question settled, but happily it is of no importance.

All the sensible phenomena of muscular contraction take place in muscles; but it is no less certain that they cannot be developed unless the brain and nerves contribute their assistance.

If you compress the brain of a man or an animal, it immediately loses the power of contracting the muscles; if you cut the nerves running to a muscle, that muscle becomes permanently paralysed.

What changes occur in the muscular structure during the state of contraction, we are completely ignorant of; for in this respect muscular contraction resembles the vital actions, of which no explanation can be given.

Not but that attempts have been frequently made to explain the action, not only of muscles but of nerves, and even of the brain, in muscular action; but none of the hypotheses which have been proposed, can be received.

Instead of stopping to examine such speculations, always easily made and easily refuted, and deserving to be for ever banished from physiology, we should observe in muscular contraction, 1. the intensity of the contraction; 2. its duration; 3. its rapidity; and 4. its extent.

The intensity of muscular contraction, i. e. the degree of force with which the fibres shorten, is regulated by the action of the brain; it is in general subject to the will, within limits which vary in each individual. A particular organisation of the muscles favours the intensity of the contractions; such is a voluminous fibre, firm, of a deep red, with transverse striæ. With the same act of volition, they would produce effects much stronger than muscles with delicate, smooth, and colourless fibres. If, however, to such fibres is added a very strong cerebral power, or a great degree of strength of volition, the contraction will acquire a remarkable degree of intensity: so that the cerebral influence on one hand, and the disposition of the muscular structure on the other, are the two elements of the intensity of muscular contraction.

A very energetic cerebral action is seldom combined with a disposition of muscular fibres favourable to the intensity of contraction. The proportion of these two elements is generally inverse. When they are combined, astonishing effects are produced. This combination probably existed in the athletæ of antiquity; it is at present observed in certain rope-dancers.

By the influence of the brain solely, muscular power may be carried to an extraordinary degree: we know the strength of an enraged man, of maniacs, of persons in convulsions, &c.

The duration of contraction is subject to the will; it must not, however, be prolonged beyond a certain period, which varies in different individuals; for we then experience a feeling of fatigue, at first but slightly marked, and afterwards increasing till the muscle refuses to contract any longer.

The period at which this unpleasant feeling commences, is proportioned to the intensity of the contraction and the weakness of the individual.

To obviate this inconvenience, the different movements are so ordered that the muscles may act in succession, the contraction of each being but of short duration: it thus appears why we cannot long remain in the same posture; why an attitude requiring the strong and continued contraction of a small number of muscles cannot be preserved more than a few moments.

The feeling of fatigue which ensues upon muscular contraction, is dissipated by inaction, and after some time the muscles regain their power of contracting.

Within a certain limit, the quickness of contraction is subjected to cerebral influence: this is proved by the manner of our common motions; but beyond this degree, the quickness of contraction evidently depends upon habit.

Consider the difference, with respect to rapidity of motion, between a man who touches a piano for the first time, and one who has been for some years in the habit of playing upon it.

Very remarkable individual differences are seen, with respect to quickness of contraction, both in our common movements and in those which are acquired solely by practice.

Will directs the extent of contraction, which, however, must necessarily vary with the length of fibres; for long fibres have a greater extent of contraction than short ones.

From what has been said, it appears that in general will has a great influence upon muscular contraction, but it is not indispensable; in many circumstances, motions occur not only without it, but in spite of it: remarkable instances of which occur in the effects of habit, passions, and diseases.

Muscular contraction, such as we have now described, must not be confounded with the modifications which it experiences in disease, as in convulsions, spasms, tetanus, wounds of the brain, &c.; neither must it be confounded with the phenomena presented by muscles after death. These phenomena are no doubt curious to study, but certainly do not deserve the importance attached to them by Haller and his disciples; and above all, they must not be united under the term *irritability*, with the other modes of contraction which occur in the animal economy, and particularly with muscular contraction.

Modifications of Muscular Contraction by Age.

The muscles cannot be distinguished from the gelatine-like matter which forms and constitutes the embryo, before the commencement of the second month; nor do they present, at this period, the characters which they have in the adult. They are of a pale grey, slightly tinged with red, and receive but a small portion of blood compared with what they afterwards receive. They grow and are developed in the progress of the growth of the body; but this evolution is not strongly marked, so that at birth they are slim and but little developed: those, however, of digestion and respiration must be excepted, which require and in fact have a much more marked increase.

During infancy and youth, the nourishment of muscles increases, but they grow chiefly in length: hence, in the child and the young man, the shape is rounded, slender, and agreeable; and nearly the same in the young girl. At adult age, the shape again changes; the muscles increase in thickness, are strongly marked under the skin, and greatly increased in size; the spaces between them being no longer filled with fat, prominences and depressions result, which give the body an appearance altogether different from that of youth. The muscular substance becomes firm, its red colour deepens, its chemical nature is modified: for the experience of every day proves, that soup made with the flesh of young animals has a taste, colour, and consistence very different from those of soup made with the flesh of adult animals. The muscles of the adult animal appear to contain more fibrine, osmazome, and colouring matter of the blood, and consequently more iron.

The nourishment of muscles decreases sensibly in old age. These organs diminish in volume, become pale, flaccid, and trembling; their contractility of tissue is weakened, the fibre becomes coriaceous and difficult to tear; and the preparation of muscular flesh in our kitchens is very different accordingly, as the animal is young or old.

Muscular contraction undergoes nearly the same alteration as the nourishment of muscles. Weak and scarcely marked in the fœtus, its activity increases at birth, and rapidly in infancy and youth; acquires its highest degree of perfection in adult age, and is at length entirely lost in the decrepit old man.

OF THE VOICE.

By VOICE is meant the sound produced in the larynx, when the air is passing through this organ, either to enter or leave the trachea.

To comprehend the mechanism by which voice is produced and modified, we must say a few words of the manner in which sound is produced, propagated, and modified in wind instruments, and principally in those which have most analogy with the organ of voice.

A wind instrument is generally formed of a straight or bent tube, in which the air is thrown into vibration by various methods.

Wind instruments are of two kinds; some *without reeds*, others *with reeds*.

In the former, such as the horn, trumpet, flageolet, flute, organ flute-pipe, the column of air contained in the pipe is the sonorous body. For sounds to be produced, it must be thrown into vibration. The means employed for this purpose are variable, according to the kind of instrument. The length, breadth, and shape of the tube, the openings in its sides or at its extremities, the mode in which the vibrations are excited, are the causes of the varieties of the sounds of this kind of instruments. The nature of the materials of the instrument influences the *timbre* only of the sound. The theory of these instruments is precisely the same as that of the longitudinal vibrations of chords.* When the physical conditions of such an instrument are known, there is nothing obscure in their

Biot. *Traité de Physique, Experimentale et Mathematique,* liv. ii. ch. ix.

theory except certain points relative to their mouth, i. e. to the manner in which the vibrations are produced. There is no evident relation between this kind of instrument and that of the voice.

Instruments with reeds are the most important for us to know, because the organ of voice is one of this description. In these instruments (clarionet, hautboy, bassoon, flute-pipe of an organ) we must distinguish the *reed*, and the *body* or pipe; the mechanism is here very different.

A reed is always formed of one, and occasionally of more thin plates, susceptible of rapid motion, and whose alternate vibrations are intended alternately to permit and prevent the motion of a current of air: hence the sounds which they produce do not follow the same laws as sounds formed by elastic plates free at one end and fixed at the other, which excite immediately sonorous undulations in free air; in reed instruments the reed alone produces and modifies the sound. If the reed is long, its movements are extensive and slow, and consequently the sounds grave; a short plate, on the contrary, necessarily produces acute sounds, because the alternate transmission and repression of the air occur more rapidly.

If we wish to derive a succession of sounds from a reed, the length of the plate must be varied: this is done in the bassoon and clarionet, when they are made to produce different sounds.

One important circumstance must however be added; the greater or less elevation of tone produced by an instrument, depends partly upon the elasticity, weight, and even form of the tongue or plate, and upon the intensity of the current of air; for if these elements change, the length remaining the same, the tone changes.*

* Biot. *l. c.*

A reed is never employed alone; it is always adapted to a tube, along which the wind driven into the reed passes, and which must consequently be open at both extremities. The tube has no influence upon the tone of the sound, but merely upon its intensity, the *timbre*, and the possibility of making the reed speak. Those which determine the most brilliant sounds, are conical tubes gradually turning outwards. If the cone is reversed, the sound becomes dull; but if two equal cones, opposed base to base, are adjusted to a conical tube, the sound acquires fulness and force. Philosophers cannot account for these modifications.*

A column of air vibrating in a tube can produce a certain number only of determinate sounds; in consequence of this fact, a reed-tube, if long, transmits with ease those sounds only which it is calculated to produce; hence a relation must in general be previously established between the reed and the body of the instrument; consequently, when we desire to produce a succession of different sounds from the same reed-tube, not only the length of the reed must be modified, but the length of the tube must be rendered proportional, which is the use of the holes bored in the sides of clarionets, bassoons, &c.: by closing or opening them, the tube is put in a suitable relation with the reed. This correspondence has moreover the advantage of making the tube, by means of the lips, easily produce the sounds which are required. This influence of the tube is well marked in those tubes which are narrow, (clarionets, hautboys): it is such that the reed will scarcely speak, if the tube is not brought to its sound. In very large tubes (organs) the reeds vibrate nearly as in the open air.

* Biot. *l. c.*

After all, we know nothing accurately of the motions of the air contained in such tubes when they are transmitting the sound produced by the reed. We have seen that the case is very different in wind instruments without a reed.

Apparatus of Voice.

Since the passage of air through the larynx is a condition absolutely requisite for the formation of voice, the organs which produce it must be reckoned among the number of the vocal organs. It is the same with many other parts which serve for the production or modification of the voice; but as we shall speak of them elsewhere, we shall at present insist upon the larynx only, which is the organ of voice properly so called.

Placed in the fore part of the neck, and forming a projection which is there visible, between the tongue and the trachea, the larynx varies in size according to age. Proportionally smaller in children and women, it is larger in the grown-up youth, and still more so in the adult.

The larynx not only produces the voice, but is also the agent of its principal modifications: hence an exact knowledge of the anatomy of this organ is indispensable to a complete comprehension of the mechanism of voice. For want of following this method, we have as yet but imperfect or wrong ideas upon this interesting point. Being unable at present to enter into all the details of the structure of the larynx, we shall insist upon those only which it is the most necessary to know, and of which many are but little known.

Four cartilages and three fibro-cartilages enter into the composition of the larynx, and in some degree form its timber-work or skeleton. The cartilages are the *cricoid*, the *thyroid*, and the two *arytenoid*. The thyroid is articulated with the cricoid by the extremity of its inferior cornua. During life, the thyroid is fixed relatively to the cricoid, contrary to the general opinion. Each arytenoid cartilage is articulated with the cricoid by means of an oblong surface, concave transversely. The cricoid presents a surface disposed in an analogous manner to that of the arytenoid, with this difference, that whereas this is convex, the other is concave. Around the articulation is a synovial capsule, tight before and behind, and loose laterally. Before the articulation is the thyro-arytenoid ligament; behind it, a strong ligamentous band, which from its attachments may be named *crico-arytenoid*.

The articulation so constituted permits lateral motions only upon the cricoid; every motion before or behind is impossible, as well as a certain see-saw motion mentioned in anatomical works, a motion which no muscle is calculated to produce. This articulation must be considered as a simple lateral ginglymus. The fibro-cartilages of the larynx are the *epiglottis* and two small bodies on the summit of the arytenoid cartilages, named by Santorini *capitula cartilaginum arytenoidarum*.

Numerous muscles are attached, directly or indirectly, to the larynx: they are termed extrinsic muscles, and are destined to move the organ altogether, whether downwards or upwards, forwards or backwards. The larynx has muscles also for the motion of its different parts. 1. The *crico-arytenoid* muscles, whose use is not, as commonly believed, to depress the thyroid towards the cricoid, but on the contrary to raise the cricoid by drawing it towards the thyroid, or even to bring the cricoid under its inferior margin.* 2. The *posterior*, and the *lateral, crico-arytenoid* muscles, whose use is to carry outwards the arytenoid cartilages, by withdrawing them from each other. 3. The *arytenoid muscle*, which approximates and applies the arytenoid cartilages to each other. 4. The *thyro-arytenoid* muscle, which of all the muscles of the larynx it is the most important to know, since its vibrations produce the vocal sounds. This muscle forms the lips of the glottis, and its inferior, superior, and lateral parts, the ventricles of the larynx. 5. Lastly, the muscles of the epiglottis, which are the *thyro-epiglottic*, the *aryteno-epiglottic*, and some fibres which may be regarded as the vestiges of the glosso-epiglottic, which is found in many animals; and the contraction of which influences the position of the epiglottis.

The larynx is lined within by a mucous membrane. This membrane, when passing from the epiglottis to the arytenoid and thyroid cartilages, forms two folds, called *lateral ligaments of the epiglottis*; it contributes to form the *superior and inferior ligaments of the glottis*. Behind, and in the substance of the epiglottis, is a number of mucous follicles and some mucous glands; there exists in the substance of the ligaments of the epiglottis a collection of these bodies, named very improperly *arytenoid* gland.

Between the epiglottis behind, and the os hyoides and thyroid cartilage before, we see a considerable mass of fatty cellular membrane, analogous to those which exist around certain joints. The use of this body is not yet determined; I think it favours the frequent sliding of the thyroid cartilage upon the posterior surface of the os hy-

* See my *Mémoire sur l'Epiglotte*, 13.

oides, and to keep the epiglottis separated above from this bone, and at the same time to furnish it with a very elastic support, favouring the purposes of this fibro-elastic cartilage in voice and deglutition.

The vessels of the larynx present nothing remarkable. The same cannot be said of the nerves; their distribution merits a careful examination. There are four of them, the superior laryngeal, and recurrents or inferior laryngeal.

The recurrent nerve is distributed to the posterior crico-arytenoid muscle, to the lateral crico-arytenoid, and to the thyro-arytenoid; no ramification of this nerve is seen to pass to the arytenoid muscle, nor to the crico-arytenoid. The superior laryngeal nerve, on the contrary, is distributed to the arytenoid muscle, which it supplies with a considerable branch, and to the crico-thyroid, which it supplies with a twig, less remarkable for its size than its course.* This twig is, however, sometimes not to be found; but the external branch of the laryngeal nerve is in this case larger. The other twigs of the laryngeal nerve are distributed to the muscles of the epiglottis, and to the mucous membrane which lines the larynx: and this part is possessed of exquisite sensibility.

The glottis is the space between the thyro-arytenoid muscles and the arytenoid cartilages. In the dead body it appears a longitudinal chink; eight or ten lines in length, and two or three in breadth: it is larger behind than before, where its two sides approach each other so as actually to touch at their insertion into the thyroid cartilage.

The posterior extremity of the glottis is formed by the arytenoid muscle.

* See my *Mémoire sur l'Epiglotte.*

If the arytenoid cartilages are made to touch by their internal surface, the length of the glottis is diminished about two thirds of its length, and presents a slit of half a line or a line in breadth, and five or six lines in length. The sides of this slit are called the *lips of the glottis.* They present a sharp edge, directed upwards and inwards, and are really formed by the thyro-arytenoid muscle and the ligament of the same name, which covers, like an aponeurosis, the muscle to which it forcibly adheres, and which, itself covered by the mucous membrane, essentially forms the finest or sharpest part of the lip. The lips of the glottis vibrate in the production of the voice: they may be styled the *human reed.*

Above the inferior ligaments of the glottis are the ventricles of the larynx, whose cavity is more spacious than it at first sight appears, and whose lower external and upper parietes are formed by the arytenoid muscle, turned upon itself: the extremity or anterior parietes is formed by the thyroid cartilage. By means of these ventricles, the lips of the glottis are completely insulated at their upper side.

Above the opening of the ventricles we see also two bodies disposed in a manner very analogous to the vocal chords, and which form, as it were, a second glottis above the first; they are termed the *superior ligaments of the glottis.* They are formed by the upper edge of the thyro-arytenoid muscle, a little fatty cellular membrane, and the mucous membrane of the larynx, which covers them before penetrating into the ventricles.

These are observations easily made upon the larynx of the dead subject. I do not think that the human glottis has ever been examined during life, at least I know of no account of this kind; but if it is examined in living animals, dogs, for instance, it is observed alternately to enlarge and contract: the arytenoid cartilages are carried outwards at the moment when the air penetrates the lungs, and approach and touch each other when the air leaves this cavity.

Mechanism of the Production of Voice.

If the trachea and larynx of an animal or of man is taken, and air forcibly driven into the trachea towards the larynx, no sound is produced, but merely a slight noise, resulting from the friction of the air against the sides of the larynx. If continuing to blow, you approximate the arytenoid cartilages to each other, so that their internal surfaces touch, a sound will be produced somewhat analogous to the voice of the animal whose larynx is employed in the experiment.

The sound will be more or less acute or grave, accordingly as the cartilages are more or less strongly pressed against each other. It will be easily seen in this experiment, that it is the inferior ligament of the glottis which by its vibrations produces the sound.

An opening made in the trachea, below the larynx, deprives men and animals of their voice; which also is restored by closing the opening. I know a man who has been in this situation many years. He cannot speak unless he wears a tight neckcloth which closes a fistulous opening in his larynx. The effect is the same when the larynx is opened below the inferior ligaments of the glottis.

On the contrary, if there is a wound above the glottis, even in the epiglottis and its muscles, if the superior ligaments of the glottis, and even the upper part of the arytenoid muscles are wounded, the voice continues. In short the glottis, if exposed in a living animal, shows at the moment when it cries, that its voice is formed by the vibrations of the vocal chords.* This, I think, is sufficient to prove that the voice is produced in the glottis by the motions of its inferior ligaments.

This fact being established, can we explain physically the formation of the voice? The following appears to me the most probable explanation. The air driven from the lungs passes first through a pretty large canal; this canal soon grows narrower, and the air is compelled to pass through a narrow slit, the two sides of which are vibrating plates, which, like the plates of a reed, alternately permit and prevent the passage of the air, and determine by these alternations, sonorous undulations in the current of the air which is transmitted.

But why, when air is blown through the trachea of a dead subject, does the larynx produce no sound analogous to the human voice? Why is the paralysis of the internal muscles of this organ followed by the loss of voice? Lastly, why is an act of the will necessary for the formation of a vocal sound? The answer is easy. The ligaments of the glottis acquire the power of vibrating like reeds, only in proportion to the contraction of the thyro-arytenoid muscles; and consequently whenever these muscles are contracted, there will be no voice.

Experiments upon animals completely accord with this doctrine. If the recurrent nerves which we have seen are distributed to the thyro-arytenoid muscles are cut, the voice is entirely lost; if only one is cut, the voice but half lost.

* The name given by Ferrein to the lips of the glottis.

I have, however, seen many animals with both recurrents divided, which uttered very shrill cries at the moment of experiencing a violent pain. These cries were very analogous to the sounds which one produces mechanically in the larynx by blowing through the trachea and approximating the arytenoid cartilages; and the phenomenon is readily explained by the distribution of the nerves of the larynx. When the recurrents are divided, the thyro-arytenoid muscles do not contract, whence *aphonia* is produced; but the arytenoid muscle, which receives its nerves from the superior laryngeal, contracts, and during a strong expiration, applies the arytenoid cartilages to each other, and thus renders the slit of the glottis sufficiently narrow for the air to throw the arytenoid muscles into vibration, even although they are not contracted.

Intensity or Volume of the Voice.

The intensity of the voice depends, like that of all other sounds, upon the extent of the vibrations.* For the more forcibly the air is driven from the chest, the greater is the extent of the vibrations of the vocal chords; and the longer these chords are, i. e. the larger the larynx is, the more extensive will be the vibrations. A vigorous person, whose chest and larynx are large, is in the most advantageous condition for intensity of voice. If this person falls sick and loses his strength, his voice will lose much of its intensity, simply because it cannot forcibly drive the air from the chest.

Children, women, and eunuchs, whose laryx is propor-

* The intensity of sound probably depends upon other causes besides the extent of the vibrations; and it must be the same with the intensity of the voice.

tionally smaller than that of the adult man, have also naturally a much less intense voice.

In the ordinary production of the voice, it results from the simultaneous motion of the two sides of the glottis : if one of these sides loses the power of exciting vibrations in the air, the voice will necessarily lose half of its intensity in an expiration of the same degree of force. This fact is proved by dividing one recurrent nerve in a dog, or by observing the voice of a person attacked with complete hemiplegia.

Note (timbre) of the Voice.

Each person has his peculiar and distinguishing note or kind of voice; every age and each sex also has its own. The kind of voice is infinitely modified; upon what physical circumstance does it depend? We are ignorant. The female note, however, which is also that of infants and eunuchs, usually coincides with the cartilaginous state of the cartilages of the larynx. The masculine voice, which occurs also in some females, appears on the contrary connected with the bony state of the same cartilages, and especially of the thyroid.

The note, it may be recollected, is a modification of sound unaccounted for by philosophers.

Of the different Tones or of the Extent of the Voice.

The sounds which the larynx is capable of producing are extremely numerous. Many celebrated authors have attempted to explain their formation; but their explanations have been rather mere comparisons.

Thus Ferrein considered the ligaments of the glottis as chords, and explained the different tones of the voice by the different degrees of tension of which he thought them susceptible: others have compared the larynx to a wind instrument, to the lips of the blower of a horn, and to the same parts in the action of whistling.

These explanations are erroneously founded, because they are established upon merely a superficial consideration of the larynx of the dead subject, whereas they ought to be founded upon a sound knowledge of the anatomy of the larynx, and an attentive examination of this organ during life: I have endeavoured to supply this deficiency, and the following are my results.

I exposed the glottis of a noisy dog, by cutting between the thyroid cartilage and the os hyoides, and I saw that when the sounds were grave, the whole length of the ligaments of the glottis vibrated, and air was expired through the whole extent of the glottis. In more accute sounds, the anterior part of the ligaments no longer vibrated, but only their posterior part, and the air passed through that portion only of the glottis which vibrated; this opening was consequently diminished.

Lastly, when the sounds were very acute, the arytenoid extremity only of the ligaments vibrated, and the air was expired through this portion only of the glottis. It appeared that the limit of the acuteness of sound had been reached, because the glottis was perfectly closed, and air no longer passed through the larynx.

The use of the arytenoid muscle being principally to close the posterior extremity of the glottis, it must be the chief agent in the production of acute sounds. I wished to know how the voice would be affected by the section of the two laryngeal nerves which give motion to this muscle; and I found that in this case the voice of the animal lost nearly all its acute sounds, and besides this acquired an habitual gravity which it had not before.

The analogy of structure is too marked between the human larynx and that of the dog, for us not to suppose that the same phenomena occur in the former. The construction of the arytenoid muscles must have a great influence upon the tones of the voice. The more forcibly these muscles contract, and the more elastic they become, the more susceptible will they be of vibrating rapidly and producing acute sounds; the less they are contracted, the more easily will they produce grave sounds. We may also presume that the contraction of these muscles powerfully assists in partly shutting the glottis, and particularly its anterior half.

It appears therefore evident, that the larynx represents a reed with a double plate, the sounds of which will be more acute in proportion as its plates are shortened, and graver in proportion as they are lengthened. But, although this analogy is just, we must not imagine there is a complete identity. In fact, ordinary reeds are made of rectangular plates fixed on one side and free on the three others; whereas the vibrating plates of the larynx, which are also nearly rectangular, are fixed on three sides and free on one only. Besides, we can cause the tones of ordinary reeds to ascend and descend by varying their length: in the plates of the larynx, it is the breadth which varies. Lastly, in musical instruments, reeds are not used with moveable plates which can vary in every instance in thickness and elasticity, as happens with the ligaments of the glottis; so that it may be readily seen, that the larynx may produce the voice, and vary the tones like a reed, but that we cannot strictly assign all the peculiarities of its action.

Till the present time it has been thought, that the tube which conveys the air to the reed, or the *porte-vent*, had no influence upon the nature of the sound produced. M. Biot relates an observation of M. Grenié, which proves the contrary. It is not therefore impossible, that the elongation or shortening of the trachea, which performs relatively to the larynx the office of *porte-vent*, may have some influence upon the production of the voice, and upon its different tones.

We have just examined the reed of the organ of voice, and must now consider the tube which its vocal sound traverses after having been produced. Now in proceeding from below upwards, the tube is composed, 1. of the space comprised between the epiglottis before, its lateral ligaments on the sides, and of the posterior part of the pharynx; 2. of the pharynx posteriorly and laterally, and of the posterior part of the base of the tongue anteriorly; 3. sometimes of the mouth, sometimes the nasal cavities, and sometimes of these two cavities together.

The tube being capable of elongation or shortening, of becoming larger or narrower, and being also susceptible of an infinite number of different forms, must fulfil extremely well the functions of a reed instrument, i. e. must be able to harmonise with the larynx, and thus to increase the production of the numerous tones of which the voice is susceptible; to increase the intensity of the vocal sound by taking a conical form turned outwards, to give roundness and agreeableness to the sound by suitably disposing its exterior opening, or nearly to stifle it, &c.

Till the influence of the tube upon instruments with reeds is determined, it is evident, that we can form only conjectures upon the influence of the tube of the vocal organ. We can make but a very few observations on this point respecting the most apparent phenomena.

A. The larynx rises in the production of acute sound, and falls, on the contrary, in the production of grave sounds; the vocal tube is consequently shortened in the first case, and lengthened in the second. We may conceive, that a short tube is more favourable for the transmission of acute sounds, while one longer is still more so for that of grave sounds. When the tube changes its length, it changes likewise its breadth; and this circumstance is remarkable, for we have seen above, that the breadth of the tube influences the facility of the transmission of sounds.

When the larynx descends, i. e. when the vocal tube lengthens, the thyroid cartilage descends, and separates from the os hyoides as much as all the height of the thyro-hyoid membrane. By his separation, the epiglottic gland is carried forwards and lodged in the concavity of the posterior surface of the os hyoides: this gland necessarily draws the epiglottis after it; whence arises a considerable enlargement of the lower part of the vocal tube.

The opposite phenomenon occurs when the larynx rises. We find the thyroid cartilage rise and then get behind the os tryoides.* By displacing and pushing backwards the epiglottic gland, the latter in its turn pushes the epiglottis, and the vocal tube becomes much shortened. By imitating this motion upon the dead body, it is readily seen that the narrowing may amount to five-sixths of the breadth of the tube. Now we adopt a wide tube to a reed which forms grave sounds; a narrow tube, on the contrary, is commonly employed to transmit acute sounds. We are therefore able, to a certain point, to explain the advantages of the changes of

* The thyro-hyoid muscles appear more particularly destined to produce the motion by which the thyroid cartilage gets behind the os hyoides.

observations of the vocal Tube

breadth which the lower part of the vocal canal experiences.

B. The presence of the ventricles of the larynx immediately below the inferior ligaments of the glottis appears to be of some use in insulating these membranes, so that they may readily vibrate in the air. When a foreign body has got into the larynx, or mucosities or a false membrane are formed in it, the voice is usually extinguished or very much weakened.

C. The epiglottis seems to belong essentially to the vocal apparatus, from its form, position and elasticity, and from the motions which its muscles are capable of giving it. But what are its uses? We have already said, that it powerfully contributes to narrow the vocal tube; but we may believe that it performs a still more important function.

M. Grenié, who has lately invented so ingenious and useful a modification of reeds, did not arrive all at once at the result which he obtained, but passed through a series of intermediate ones. At one period of his labours, he wished to augment the intensity of a sound, without in any degree changing the reed. In order to succeed, he was compelled gradually to increase the current of air; but this augmentation, by rendering the sounds stronger, made them rise. M. Grenié found no other mode of obviating this inconvenience, than placing a supple elastic tongue, such as the epiglottis is above the glottis, obliquely in the tube, and immediately above the reed; whence we may conclude, that the epiglottis contributes to give us the power of increasing our vocal sounds without making them rise.

D. The intensity of the voice is evidently influenced by the vocal tube. The most intense sounds that the voice can produce, require the mouth to be very open, the tongue drawn a little backwards, and the velum of the palate raised and rendered horizontal and slightly elastic, closing all communication with the nasal fossæ. In this case, the pharynx and mouth clearly act as a *porte-voix*, i. e. they exactly represent a pipe with a reed, which turns outwards, and the effect of which is to augment the intensity of the sound produced by the reed. If the mouth is partly shut and the lips carried forwards and slightly approximated, the sound will acquire roundness and agreeableness, but will lose its intensity; an effect which is readily explained by what has been already said of the influence of the shape of the tubes in instruments with reeds.

For the same reason, as often as the vocal sound passes through the nasal fossæ, it becomes dull, for the form of these cavities is well calculated to diminish the intensity of sounds. If the mouth and nose are shut at the same time, no sound is produced.

E. We have seen that when the voice is produced, many of the modifications of note *(timbre)* arise from the changes which the lips of the glottis experience in thickness and elasticity. The tube may produce numerous others, according to its various degrees of length and breadth; according to its form, the contraction of the pharynx, the position of the tongue, and of the velum pendulum palati; accordingly as the sound passes altogether or in part through the mouth, or the nasal fossæ, or through both at once; according to the individual disposition of the mouth or nose; the volume of the tongue, &c. According to all these circumstances, the note *(timbre)* of the voice is continually modified. Every time, for example, that the sound traverses the nasal fossæ, the sound becomes disagreeable, *nasal*.

Those are mistaken, who imagine that the nasal cavities can increase the intensity of their sound by reverberation; these cavities can produce the opposite effect only: thus as often as any cause allows the sound to enter them, the voice becomes dull or *nasal.*

F. Independently of the numerous modifications produced in the intensity and the note of the voice by the tube of the vocal organ alternately permitting or preventing its production, another very important kind of modification is in the same way produced. By this means the sound is divided into small portions, each of which has a distinct character, because each is produced by a particular motion of the tube. This kind of influence of the vocal tube *is the power of articulating*, which presents an infinite number of individual differences, corresponding with the peculiar organisation of the vocal tube.

We have hitherto treated of the voice in a general manner, and shall now speak of its principal modifications, viz. *the cry, or native voice; the voice properly so called, or acquired voice; speech, or articulate voice; and singing, or appreciable voice.*

Of the Cry, or Native Voice.

The cry is a sound which cannot be appreciated, and like all the sounds produced by the larynx may vary in tone, intensity, and note.

The cry is easily distinguished from all other voca sounds: but as its character depends upon the note, it is impossible to explain physically the difference between these and cry.

Whatever may be the condition or age of a man, he is able to produce cry, or to cry. The new-born infant, the idiot, the savage, the person deaf from his birth, the civilised man, the decrepit old man, can all utter cries; crying must therefore be regarded as necessarily attached to organisation, of which fact we shall be more convinced by examining its uses.

By cry, we express lively sensations, whether produced from within or from without, whether agreeable or disagreeable. There are cries of joy and cries of pain. By cry, we express our most simple instinctive wants, our natural passions. There is a cry of fury, another of fear, &c.

The social wants and passions not being an indispensable consequence of organisation, and requiring civilization for their developement, have no cries peculiar to themselves.

Cry usually comprehends the most intense sounds which the voice can form; its note has most frequently something which wounds the ear and acts strongly upon those who hear it.

By means of cry, important relations are established between men. The cry of joy disposes to joy; the cry of pain excites pity; the cry of terror spreads dread far around. This kind of language is found in most animals, and is almost the only one of which they are possessed: the singing of birds must be regarded as a modification of their cry.

Of acquired Voice, or Voice properly so called.

In the usual condition of man, i. e. when he is living in society and possessed of hearing, he discovers from his earliest infancy, that his race utter sounds which are not cries; he soon remarks that he can form similar ones with his own larynx; and from this moment, what is termed *acquired voice* is developed in him, by the effect of imitation and of the advantages which are attached to it. A deaf infant cannot make these remarks, and therefore cannot *acquire* this kind of sound.

Voice appears to differ from cry merely in intensity and note, for it also is formed of sounds which cannot be appreciated, or of sounds the intervals of which are not accurately distinguished by the ear.

Since the voice results from hearing and an intellectual operation, it cannot be developed if the circumstances which produce it do not exist. In fact, infants deaf from birth, who can have no idea of sound, and idiots, who are unable to establish any relation between the sounds which they hear and those which their larynx can produce, have no voice, although the vocal apparatus of both is fit to form and modify sounds as well as in well-constituted individuals.

For the same reason, individuals improperly called savages, because found wandering in forests from their infancy, can have no voice, as the intellect is not developed in the solitary state, and requires social existence. The note, intensity, and tone of the voice, are susceptible of numerous modifications by means of the larynx; and further, the vocal tube has a powerful influence upon the voice; speech and singing are but modifications of the social voice.

It is difficult, perhaps even impossible, to say how man has become able to represent his intellectual acts by modifications of his voice; how he has arrived at the composition of languages, and especially how he could compose an alphabet. This knowledge would undoubtedly be curious and useful, but it is not indispensable, and besides does not belong to physiology. The mechanism only of language must engage our attention.

A language is composed of words, and words are the signs of ideas; but words themselves are formed of letters or alphabetical sounds, which for the most part are modifications of the voice.

Grammarians distinguish letters into *vowels* and *consonants;* this distinction cannot suit physiologists.

Letters must be distinguished into those which are truly modifications of the voice, and those which may be formed independently of the voice.

The letters which belong to the voice are, as far as regards European letters, *a* very open, or English (hâll); â French (hâle); *a, è, é, e* mute French; *i, o,* open Italian; *o, eu, u,* French; *u* Italian. Each of these letters may be doubly modified, as we signify by saying that it is long or short; these are the vowels of grammarians. The other vocal letters are *b* and *p* (labial consonants), *d* and *t* (dental consonants), *l* (palatine consonant), *g* and *k* (guttural consonants), *m* and *n* (nasal consonants)

As the formation of vowels simply requires the vocal tube to be open, it depends upon the form which this assumes during the production of the voice. Vocal consonants suppose the tube closed, and result from the manner in which it is opened when the voice is formed; the existence of these latter letters is therefore instantaneous.

The other letters are *f* and *v*, the two sounds of *th* English, *s* and *z, ch, j, r, h,* and *x* Spanish or *χ* Greek.

The character of these letters is that of being produced by the friction of the air against the sides of the mouth, of being consequently independent of the vocal sound, and of being capable of prolongation during the whole time that air is passing from the lungs.

Each letter, vowel, or consonant, is produced by a particular disposition or motion of the vocal tube; the tongue is the principal agent of some, the teeth of others, the lips, again, of others; and in the production of others, the voice must traverse the nasal fossæ, &c.

Pronunciation requires a proper conformation of the vocal tube. If it is in any way injured, if the hard or soft palate is perforated, the teeth deficient, the tongue swelled or paralysed, &c. the power of articulation is altered or lost.

The simple noise made by the air when passing the larynx is sufficient for pronunciation, as happens when we speak very low. Persons who have completely lost their voice pronounce with sufficient distinctness to be heard at some distance.

By combining letters in various ways and numbers, we form sounds more or less compound, which are words.

The formation of words is different in different languages. In those of the north, consonants are accumulated, although this is not the cause of their roughness and difficult pronunciation. In those of the south, vowels are employed in larger numbers, and southern languages are generally soft and harmonious.

The same sound does not always serve as the basis of articulation: articulate voice rises, falls, and varies in intensity and tone, differently in every language. The mode of these variations constitutes the *accent* or peculiar pronunciation of every country.

Articulating, pronouncing, is not speaking. A bird pronounces words, even phrases, but does not speak. Man alone is gifted with *speech,* which is the most powerful means of expression possesed by the mind; he alone also attaches a meaning to the words which he pronounces, and to the arrangement which he gives them; without his intellect he could not speak. In fact, most idiots cannot speak;* they articulate sounds vaguely, which have, and can have, no signification.

Singing.

The voice of singing differs from other sounds produced by the larynx, in being formed of appreciable sounds, the intervals and harmony of which the ear can appreciate. These characters are common to neither *cry* nor *speech*, the sounds of which are inappreciable.

Dodart has advanced, that in the production of singing, the larynx experiences a balancing or oscillatory motion from below upwards; but his assertion is not confirmed by observation.

It is probable that in singing the ligaments of the glottis are disposed in a peculiar manner, which circumstance enables them to form appreciable sounds.

We remark very important individual differences in the extent, strength, note, &c. of the voice when singing.

An ordinary voice has usually about nine tones between its lowest and its highest sound; the most extensive voice seldom exceeds two octaves of just and full sounds.

There are two kinds of voices, *grave* and *acute*: their difference is about an octave.

In general grave voices belong to adult men; however, those with the gravest voices can produce acute sounds by their *falsetto*.

Acute voices are those of women, children, and eunuchs.

* Pinel, *Traite de la Manie*, p. 167.

By adding all the tones of an acute to those of a grave voice, we have an extent of about three octaves. No one individual appears possessed of this extent of voice in pure and agreeable sounds.

Musicians establish differences also among base voices; *high counter, tenor, base,* &c.

But the differences which exist among different kinds of voices do not all regard extent. There are *strong* voices, whose sounds are strong and noisy; *sweet* voices, whose sounds are sweet, and like those of the flute; *fine* voices, whose sounds are full and harmonious; *just* voices; *false* voices; *flexible, pliant* voices, *hard* and *heavy* voices. Some have their good sounds irregularly distributed, some in their base, others in their treble, others between, &c.*

Singing, like voice and speech, is the effect of society. It supposes an ear and understanding. It is generally employed to signify instinctive wants, passions, different states of mind: joy, sorrow, successful or unsuccessful love, excite different kinds of song.

Singing may be articulate. Then instead of expressing feelings only, it becomes the means of expressing most acts of the understanding, but particularly those which are connected with the *social* passions.

Declamation is a particular kind of singing; only the intervals of the tones are not quite harmonic, and the tones themselves are not quite appreciable. The declamation of the ancients differed much less from singing than ours: it was probably analogous to the *recitative* of our operas.

Southern languages which are very much accentuated,

* J. J. Rousseau, *Dictionnaire de Musique.*

i. e. which have a great variety of tones in common pronunciation, are very well calculated for singing.

All the modifications of the voice which we have just studied are produced when the air is leaving the chest. Voice may be formed also when the air is passing the larynx on its way to the lungs; but this *inspiratory* voice is hoarse and unequal, and of but little extent; its tones can be with difficulty varied; lastly, from the character of the same phenomenon, we may judge that it is not a natural occurrence. Speaking too and singing are possible during inspiration. We are not acquainted with the modifications experienced by the lips of the glottis in the production of inspiratory voice.

Art of Ventriloquists.

Since man is able infinitely to vary, if we may so say, the appreciable or inappreciable sounds of his voice, and can at pleasure change in a thousand ways its intensity, note, &c. nothing can of course be easier than for him to imitate with exactness the different sounds which strike his ear: and he in fact does this in many circumstances. Many persons imitate perfectly the voice and pronunciation of others, of actors for instance. Sportsmen imitate the different cries of game; and in this way succeed in alluring it into their nets.

This power of imitating noises or sounds constituses an art; but the individuals who possess it, and are called ventriloquists, have not any peculiarity of organization; they have merely well arranged organs of voice and speech, so as readily to produce the necessary sounds.

The foundation of this art is easily understood. We have instinctively observed, that sounds alter from many causes; that, for instance, they become weak, less distinct, and change their note in proportion to their distance. If a man goes to the bottom of a well, and wishes to speak to persons at its edge above, they will hear his voice modified by the distance and form of the canal which it has passed through. If therefore a person attentively remarks these modifications and endeavours to produce them, he will accomplish an acoustic illusion, which cannot be avoided any more than we can avoid seeing objects larger when we look through a magnifying glass; the error will be perfect, if tricks are at the same time played to distract our attention.

The greater the talents of the performer, the more numerous will be the illusions; but we must not believe that a ventriloquist* produces vocal sounds and articulates differently from other persons. His voice is formed in the ordinary way: he merely modifies its volume at pleasure; and if he happens to speak without moving his lips, it is because he takes care to employ words in which there are no labial consonants, which would inevitably require motion of the lips for their formation. In a certain sense we may say, that his art is to the ear, what painting is to the eye.

Modifications of the Voice by Age.

The larynx is proportionably very small in the fœtus and new-born child: its small size forms a contrast with the size of the os hyoides, the tongue, and other organs of deglutition, which are already greatly developed. It is besides rounded; the thyroid cartilage forms no projection in the neck.

* The words ventriloquist, ventriloquism, &c. &c. might be employed in the infancy of science, but they ought evidently to be no longer employed in scientific language.

The lips, ventricles, and superior ligaments of the glottis are very short in proportion to what they are subsequently; for the thyroid cartilage being but little developed, the space which they occupy is necessarily small. The cartilages are flexible, and far from having the firmness which they afterwards possess.

The larynx preserves these characters nearly till puberty: at this period a general revolution takes place in the economy. The developement of the genital organs determines a rapid increase of nutrition in most organs, and among the rest, in the organs of voice.

The greater activity of nutrition is first observable in the muscles; it is then seen, but more slowly, in the cartilages: at this time the general form of the larynx is modified, the anterior part of the thyroid cartilage is evolved and forms a projection in the neck, much more striking in the female than the male. Hence results a considerable elongation of the lips of the glottis, or of the thyro-arytenoid muscles, and this phenomenon is more worthy of remark than the general enlargement of the glottis, which occurs at the same time.

These changes of the larynx, although rapid, are not instantaneous; they take up six or eight months for their completion.

After puberty the larynx undergoes no farther remarkable changes; its volume and the projection of the thyroid cartilage merely become more conspicuous.

In the adult man, the cartilages become partially ossified.

In old age, the ossification of the cartilages proceeds and becomes almost complete; the epiglottic gland diminishes considerably, and the internal muscles, especially those which form the lips of the larynx, decrease in size, Modification of voice by age

redness of colour and in elasticity: in short they experience the same kind of changes as the muscular system in general.

As the production of voice supposes the entrance and departure of the air of the chest, the fœtus plunged in the *liquor amnii* can have none; but at the very moment of birth, the child can emit very intense acute sounds.

Vagitus is the name given to this voice or rather cry of infants, by which the child expresses its wants, its feelings. This, it may be recollected, is the object of cry.

Towards the end of the first year, the child begins to form sounds which are easily distinguished from the vagitus. These, at first vague and irregular, soon become more distinct and connected: then it is that nurses begin to make them pronounce the most simple sounds, and afterwards those which are more complicated.

The pronunciation of children is far from resembling that of adults; but what a difference is there not also in their organs! In infants the teeth have not left the alveoli; the tongue is comparatively very large; the lips are larger than sufficient to cover the front of the jaws when approximated; the nasal cavities are but little evolved, &c.

Children attain the accurate articulation of different combinations of letters by degrees only, and in proportion as their organs of pronunciation more resemble those of the adult. They cannot form appreciable sounds or sing till long after they have acquired the power of speaking.

This description of sounds is the proper or acquired voice: the child would not utter them if deaf. It must not be considered as a modification of vagitus.

Till the period of puberty, the larynx remains proportionally very small, as well as the lips of the glottis: the voice too is entirely composed of acute sounds.

It is physically impossible for the larnyx to produce grave ones.

At puberty, especially in man, the voice undergoes a remarkable modification. It acquires in the space of a few days, often instantaneously, a gravity and dull note to which it was before a stranger. It falls in general an octave. The voice of the young man *breaks*, according to the common expression. In some cases, the voice is completely lost, and is not repaired for several weeks: it even frequently contracts a remarkable degree of *hoarseness*. Occasionally the young man involuntarily utters a very acute sound when he wishes to utter a grave one; it is scarcely in his power at that time to utter appreciable sounds or to sing correctly.

This situation of things continues sometimes for a year, after which the voice regains a more or less clear note, which remains during the rest of life; but we meet with individuals who, while their voice is breaking, for ever lose the power of singing; others who, having had a fine and extensive voice previously, have but an indifferent and limited one after this period.

The gravity which the voice acquires evidently depends upon the developement of the larynx, and especially upon the elongation of the lips of the glottis. As these parts cannot be elongated backwards, they are elongated forwards: at this time it is that the larynx forms a projection in the neck,—that the *Pomum Adami* appears. In the female, the lips of the glottis do not present this increase of breadth at puberty, and their voice generally remains acute.

The voice preserves nearly the same characters beyond the age of puberty: at least the modifications experienced in the interval are slight, and scarcely affect any thing but the note and volume. Towards the commencement of old age, the voice changes again, its note alters, its extent diminishes; singing is more difficult; sounds become crying, and are no longer produced without trouble and fatigue. The organs of pronunciation being altered by age, the teeth being shorter, and some generally having indeed fallen out, pronunciation is sensibly affected.

All these phenomena become more marked in confirmed old age. The voice is weak, tottering and broken; singing has the same characters, which depends upon the manner in which the muscles contract. Speech likewise undergoes remarkable modifications; the slowness of the tongue's movements, the absence of the teeth, the greater proportionate length of the lips, must necessarily influence the pronunciation.

Relations of Hearing and Voice.

We have already mentioned the connection of hearing and voice; it is such that a child deaf from birth is necessarily dumb, that a person with a false ear has necessarily a false voice, that a person hard of hearing instinctively speaks loud.

The larynx, however, must not be thought incapable of producing voice in persons born deaf: we have already said that it produces cry. It is led, by different modes, to produce voice; even persons dumb from birth are enabled to speak and keep up a conversation, but their voice is hoarse, dull, unequal; the different inflections occur unequally and without a motive. I do not think that a person deaf and dumb from birth has ever been taught to sing.

Some persons have gained their hearing at an age when they could describe their sensations; and in all of them the voice was developed quickly after.

The *Mémoires de l'Académie des Sciences* for the year 1703, contain an example of this kind, which occurred in a young man of Chartres, twenty-four years of age, "who to the great astonishment of all the city began suddenly to speak. They were informed by him that three or four months previously he had heard the sound of the clocks, and had been extremely surprised at this new and strange sensation; that afterwards a kind of water had run out of his left ear, and he heard perfectly with both ears. He was listening these three or four months without saying any thing, accustoming himself to repeat in a low voice the sounds which he heard, and strengthening himself in pronouncing and understanding the meaning of words. At length he thought himself qualified to break silence, and declared that he spoke, although imperfectly. Immediately some able theologians interrogated him, &c."

It is unfortunate for science that this young man was not examined by physicians; perhaps his history would have then become interesting.

A similar circumstance occurred a few years ago at Paris. A young person, deaf and dumb from birth, was cured of deafness by Dr. Itard, by means of injections thrown into the tympanum through an opening in the membrana tympani. The young man first heard the sound of the neighbouring clocks, and experienced a very great emotion, and even had the head-ach, vertigo and dizziness. The next day he heard the bell of the room; twenty-eight days afterwards he perceived the voices of persons who were speaking. Then his rapture was extreme; he could not hear them talk enough. "His eyes, (said Professor Percy) followed speech even to the lips." His voice soon became developed. He at first formed vague sounds only; soon afterwards he could stammer out some words, but he pronounced them badly and like a child. Some time elapsed before he could pronounce words rather compound and containing many consonants. They played an old organ in his hearing, without preparing him for it; he suddenly began to tremble and grow pale, and he nearly fainted, and aftewards experienced all the transports of a lively and novel pleasure; his glowing cheeks, sparkling eyes, hurried respiration, and rapid pulse, announced a kind of delirium, intoxication, and happiness.

Many other surprising phenomena would no doubt have been observed in this young man, if a disease had not snatched him from the philosophical physicians who were watching him.

Of Sounds independent of Voice.

Independently of voice, man can also produce at pleasure a number of inappreciable and even appreciable sounds, such as the noise of spitting or blowing one's nose; of calling a horse; that which resembles the sound of decanting a bottle; whistling by the teeth or lips, whether formed during inspiration or expiration; and a multitude of other sounds which result from the motion of the different parts of the mouth, and from the manner in which the air enters or leaves this cavity. It is not easy to explain the mechanism of the production of these different sounds, particularly of the appreciable, as in the action of whistling: our data on this point are but approximations

OF ATTITUDES AND MOTIONS.

Muscular contraction is not only the cause of voice; it also presides over our motions and attitudes.

The explanation of human motions and attitudes consists in the application of the laws of mechanics to the organs which execute them.

As our attitudes and motions are extremely various, they cannot be explained without the application of most of the laws of mechanics.

No one has yet engaged in this labour in a satisfactory manner: the most usual attitudes and motions, and the application of the most simple mechanical principles, have hitherto been attended to alone.

Mechanical Principles necessary for understanding Motions and Attitudes.

The line in which a body gravitates is called vertical.

In each position of the body the vertical line passes through different points: but there is one point in which all the directions of this force cross one another: this is called *the centre of gravity.*

The condition of equilibrium in a gravitating body, placed upon a horizontal plane, is that the perpendicular line, dropped from the centre of gravity upon the horizontal plane, falls between the points on which the body rests.

The equilibrium of a body gravitating upon a horizontal plane is so much the more stable, as the centre of gravity is nearer the plane, and as the surface of support is more extensive.

The base of support is the space between the points in which the body rests on the plane.

Of two hollow columns, consisting of the same quantity of matter, and of the same height, that with the largest cavity will be the stronger.

Of two columns of the same diameter, but of different heights, the weaker will be the higher.

The greatest weight that a spring with small flexions can support is proportional to the square of the number of flexions, plus one; so that if the spring presents three curves, it will support a weight sixteen times heavier than if it had none.

Of Levers.

A lever is defined to be an inflexible line, turning round a fixed point.

We distinguish in a lever the point of support, the point at which the power acts, and that where the resistance is excited, or simply the point of support, the power and resistance.

According to the relative positions of the point of support, of the power and of the resistance, the lever is of the first, second, or third kind.

In the lever of the first kind the point of support is between the resistance and the power; the resistance is at one extremity, and the power at the other.

In the lever of the second kind the resistance is between the power and the point of support, and the point of support and the power are at the two extremities.

Lastly, in the lever of the third kind, the power is between the resistance and the point of support, while the resistance and the point of support are at the two extremities.

The arm of the power, and that of the resistance, are distinguished in a lever. The first comprises the portion of the lever between the point of support and the power; the second of that portion of the lever which separates the point of support from the resistance.

When in a lever of the first kind the point of support occupies exactly the centre of the lever, the lever is said to have equal arms; when the point of support is nearer the power or the resistance, it is said to have unequal arms.

The length of the arm of a lever gives more or less advantage to the power or to the resistance. If, for instance, the arm of the power is longer than that of the resistance, the power has the advantage in the proportion of the length of its arm to the length of the arm of the resistance: so that if the first of these arms is double or treble the length of the second, the power may be equal to half or one-third of the resistance, and yet the two forces will be in equilibrium.

In the lever of the second kind the arm of the power is necessarily longer than that of the resistance, as the latter is between the power and the point of support, while the power is at one extremity. This kind of lever always gives advantage to the power.

The contrary occurs in the lever of the third kind, as in this the power is placed between the resistance and the point of support, while the resistance is at one extremity.

The lever of the first kind is the most favourable to equilibrium; the lever of the second kind is the most favourable for overcoming a resistance; and the lever of the third kind is the most favourable for rapidity and extent of motion.

It is important to remark the direction in which the power is inserted into the lever. The effect of the power is so much the more considerable as its direction becomes more perpendicular to that of the lever. When the latter condition is fulfilled, the whole of the force is employed in overcoming the resistance, whereas in oblique directions one part of this force tends to move the lever in its own direction, and this portion of the force is destroyed by the resistance of the point of support.

Moving Power.

Inertia is that general property of bodies by virtue of which they remain in their state of rest or repose, as long as no foreign cause acts upon them.

The force which produces motion must be measured by the quantity of motion produced. This again is estimated by multiplying the mass by the rapidity acquired.

This rapidity may be acquired in two different ways; either by the continued action of a power, as that of gravity, or by the effect of a force which instantaneously produces a limited rapidity.

We may easily conclude, from what has been said, that every effort exerted upon a detached body will produce motion. The direction of this motion, the rapidity acquired, and the space passed through by the body, will depend upon its mass, or the effort, upon the intensity of the action exerted upon it, and upon the forces which are applied to it during its motion.

Thus a body projected by the hand instantaneously acquires a rapidity so much the greater as the effort is greater and the mass smaller: the continued action of the weight incessantly modifies both this rapidity and the direction of the motion, which ceases when the body has fallen upon the surface of the earth. The motion is also impaired by the resistance of the air, the effect of which increases with the rapidity of the body, with the extent of the surface which constantly strikes the air, and with the specific levity of the body.

Friction is the resistance to be overcome in making one body slide upon another.

Adhesion is the force which unites two polished surfaces, applied one to the other. This force is measured by the perpendicular effort necessary to be made at the surface of contact to separate the two bodies.

The more polished the surfaces of contact, the greater is the adhesion and the weaker the friction; also, as long as the object is simply to make two bodies slide one upon the other, there will always be an advantage in polishing the surfaces, or interposing a liquid between them.

Of the Bones.

The bones, which determine the general form and the dimensions of the body, fulfil, on account of their physical properties, a very important purpose in the different positions and motions of the body; they form the different levers of the animal machine, and transmit the weight of our parts to the earth. They are employed as levers, sometimes of the first kind, sometimes of the second or of the third. When equilibrium is required, a lever of the first kind is almost always employed; if a considerable resistance is to be overcome, they represent a lever of the second kind. In other motions they are employed as levers of the third kind, which, as we know, being disadvantageous to the power, favours the extent and rapidity of motion. Most of the prominences and eminences of bones are intended to change the direction of the tendons, to render their insertion further from the perpendicular.

As means of transmitting the weight, the bones represent erect columns, almost always hollow: whence the resistance of the skeleton in general, and of each particular bone, is increased.

Form of the Bones.

The bones are divided into short, flat, and long.

The short bones exist in parts requiring much solidity and little mobility, as in the feet, the vertebral column.

The chief use of the flat bones is to form the sides of cavities; they, however, contribute advantageously also to the motions and attitudes, by the extent of the surface which they present for the insertion of the muscles.

The long bones are principally intended for locomotion; they exist in the limbs only.

The shape of their bodies and of their extremities deserve attention. The body is the part of least bulk, and is generally rounded; the extremities, on the contrary, are always more or less voluminous.

The disposition of the body of a bone contributes to the elegance of the form of the limbs: the volume of the articular extremities, besides the same purpose, secures the solidity of the joints, and diminishes the obliquity of the insertion of the tendons into the bones.

The short bones are almost always composed of a spungy substance, whence they present a considerable surface, without being too heavy. It is the same with the extremities of the long bones, but the body of the latter presents a large quantity of compact substance, giving it great power of resistance, which was requisite, because all the efforts which the long bones sustain, terminate in their bodies.

The spungy substance of the short bones, and of the extremities of the long ones is filled by medullary juice.

The cavity of the bodies of the long bones is filled with marrow.

Articulations of the Bones.

The articulations are distinguished into those which do not allow of motion, and those which do.

The first division presents subdivisions, founded upon the form of the articular surfaces.

The second presents others founded on the disposition of the articular surfaces, and the description of motion which the articulations permit.

In the moveable articulations, the bones never touch immediately; there is always between them an elastic substance, differently disposed, according to the articulation, and calculated to support strong pressure with ease, to weaken shocks, and favour motion. Sometimes this substance is supple, adheres equally to the surface of the two articulating bones, and constitutes articulations of *continuity*.

It is then of a fibro-cartilaginous nature. Sometimes this substance forms a bed upon each articular surface; this is observed in articulations of *contiguity*. In this case the substance is cartilaginous.

It is said, that the substance which invests the bones in this kind of articulation, is formed of fibres parallel to each other, and perpendicular to the articular surface which they invest; we think this opinion requires more examination. The cartilages appear rather to be formed of an homogeneous layer.

The articulations thus disposed, present the most favourable disposition for sliding motions.

The surfaces which are in contact are very polished, and a particular fluid, called *synovia,* continually exists between them. For the same reason, the adhesion is very great, and this circumstance adds to the solidity of articulation, by contributing to prevent displacement.

In certain moveable articulations, between the articular surfaces, are found fibro-cartilaginous substances, not adhering to these surfaces. They are thought to form cushions, which, yielding to pressure and afterwards recovering themselves, protect the articular surfaces to which they belong. They are found, it is said, in those articulations which sustain the greatest pressure.

This opinion appears to us not sufficiently founded. In fact, the articulation of the hip, and especially of the foot, which habitually sustain the greatest pressure, have no such substance. Do they not rather serve to favour the extent of motion, and prevent dislocation?

Around, and sometimes within the articulations, are found fibrous bodies, called *ligaments,* which have the twofold use of maintaining the bones in their respective situations, and of limiting their motions upon each other.

Attitudes of Man.

Let us examine man in the different positions in which he is capable of being, and first in his most common position, i. e. on his feet.

We see, in the first place, that the head, intimately united to the atlas, forms with it a lever of the first kind, whose point of support is in the articulation of the sides of the substance of the atlas, and of the axis, while the power and the resistance occupy each an extremity of the lever, represented the one by the face, the other by the occiput.

The point of support being nearer to the occiput than to the fore part of the head, the face tends, by its weight, to fall forwards: but it is kept in equilibrium, by the contraction of the muscles attached to its posterior part. The vertebral column, therefore, supports the head and transmits the weight of it to its lower extremity.

The superior limbs, the soft parts of the neck and thorax, the greatest part of the abdominal viscera, gravitate, mediately or immediately, upon the vertebral column.

On account of the great weight of these parts, the vertebral column requires great solidity.

In fact, the bodies of the vertebræ, the intervertebral fibro-cartilages, and the various ligaments which unite them, form a whole of great solidity. If we again consider, that the vertebral column is formed of portions of erect cylinders; that it resembles a pyramid, whose base rests upon the sacrum; that it presents three curves in opposite directions, which give it sixteen times more resistance than if it had none, we shall have an idea of the resistance of the vertebral column. We also see it support not only the weight of the organs which gravitate upon it, but even frequently very heavy loads.

The weight of the organs supported by the vertebral column, being felt especially at the fore part, muscles placed along its posterior part, resist the tendency which it has to fall forwards. Under these circumstances, every vertebra, and the parts attached to it, represent a lever of the first kind, whose point of support is the fibro-cartilage which sustains the vertebra; whose power is in the parts which draw it forwards; and whose resistance is in the muscles which are attached to its spinous and transverse processes.

The vertebral column, taken altogether, represents a lever of the third kind, whose point of support is in the articulation of the fifth lumbar vertebra with the os sacrum; whose power is in the parts which tend to draw the column forwards; and whose resistance is in the posterior muscles. As the power acts principally upon the inferior part of the lever, nature has there placed the strongest muscles; there the pyramid, represented by the vertebral column, has the greatest thickness, and there the vertebral processes are more marked and horizontal; there, lastly, it is that we feel fatigue, after standing a long time.

The muscular power will act the more effectually in establishing the equilibrium necessary for standing, in proportion as the spinous processes are larger and more horizontal.

The weight of the vertebral column, and the parts gravitating upon it, is transmitted directly to the pelvis, which, resting upon the thighs, represents a lever of the first kind, whose point of support is in the ilio-femoral articulations, and whose power and resistance lie before or behind

The pelvis supports also the weight of part of the abdominal viscera.

The sacrum supports the vertebral column, and acting like a wedge, it transmits equally to the two thighs, by means of the ossa ilii, the weight with which it is loaded.

The pelvis is truly in equilibrium upon the two heads of the thighs; but this equilibrium results from the combination of many efforts.

On the one hand the abdominal viscera, pressing upon the pelvis, which is inclined forwards, tend to depress the pubis; on the other hand, the vertebral column tends by its weight to give the pelvis a see-saw motion backwards.

The weight of the vertebral column being much greater than that of the abdominal viscera, it might appear, that to establish an equilibrium, some muscular powers would be sufficient, which rising from the thigh should be attached to the pubis, and enabled, by their contraction, to counterbalance the excess of the weight of the vertebral column.

Those muscles in fact exist, but they are not the chief agents in producing the equilibrum of the pelvis upon the thighs; for the pelvis, far from tending to slide backwards, would rather incline to be carried forwards; because the muscles which resist the tendency of the vertebral column to incline forwards, having their fixed point on the pelvis, make a considerable effort to draw it upwards. The muscles, therefore, which run from the thigh to the posterior part of the pelvis, prevent the latter from rising, and are the principal agents of the equilibrum of the pelvis upon the thighs; and nature has made them very numerous and strong.

The articulation of the thigh with the ossa ilii is nearer the pubis than the sacrum, whence it follows, that the posterior muscles act with a larger lever; which circumstance is favourable to their action.

In the usual state of standing, the thighs transmit the weight of the trunk directly to the tibia. They accomplish this easily, from the solidity of their articulation with the ossa ilii.

The neck of the thigh, besides its use in motion, is of utility in standing, by directing the head of the thigh obliquely upwards and inwards: whence it supports the vertical pressure of the pelvis, and resists the separation of the ossa ilii which the sacrum has a tendency to produce.

The femur transmits the weight of the body to the tibia; but, from the mode in which the pelvis presses upon it, its inferior extremity has a tendency to be carried forwards, while the upper, on the contrary, inclines backwards: whence it follows, that to maintain it in equilibrium on the tibia, powerful muscles are required which may oppose this motion. These muscles are the rectus anterior and triceps femoris, whose action is favoured by the presence of the rotula placed behind their tendon. The muscles of the posterior part of the leg, which are attached to the condyles of the thigh, also contribute to maintaining this equilibrium.

The tibia transmits the weight of the body to the foot; the fibula has no share in this. But, for the former bone to fulfil this office properly, muscles are requisite which may oppose the tendency of its upper extremity to be carried forwards. The gemelli and soleus chiefly accomplish this end: all the other muscles of the posterior part of the leg contribute to it.

The leg supports all the weight of the body: its form and structure correspond with this use. The sole of the foot has a great extent, which contributes to the solidity of standing. Its skin and epidermis are very thick. Above the skin is a fatty layer, very thick, especially in those parts where the foot presses on the ground. This fat forms a kind of elastic cushion, calculated to weaken or diminish the effects of pressure from the weight of the body.

The foot does not touch the ground through its whole extent; the heel, the external edge, the part corresponding to the anterior extremity of the metatarsal bones, the point or pulp of the toes, are the points which habitually touch the ground and transmit the weight of the body to it, and in each of these points are considerable bundles of fat, evidently intended to oppose the effects of too strong a pressure. That which is placed immediately below the os calcis is very remarkable; it is smooth on its upper surface, and merely contiguous to the bone, and is likewise distinct from the rest of the fat of the heel. The other packets or cushions of fat are smaller, but disposed in a similar manner.

The tibia transmits the weight of the body to the astragalus, and this again to the other bones of the foot: but the os calcis receives the greatest part of it; the rest is divided among the other points of the foot which rest upon the ground.

This is the general mode of this transmission. The effort sustained by the astragalus is transmitted, 1. to the os calcis; 2. to the os scaphoides. The os calcis being placed immediately under the astragalus, receives the greatest share of the pressure, and transmits it partly to the ground and partly to the os cuboides. The latter bone and the os scaphoides press in their turn, by means of the ossa cuniformia, upon the metatarsal bones, which resting upon the ground, transmit to it nearly the whole pressure which they sustain: the surplus is distributed to the toes, and at length likewise terminates on the base of support. This mode of transmission supposes the foot to touch the ground through the whole extent of the sole.

As the pressure of the tibia is felt particularly at the inner part of the foot, the latter has constantly a tendency to be thrown outwards. The fibula is intended to preserve the foot in the straight position requisite for the solidity of standing.

We have seen that the muscles which prevent the head from falling forwards, when we stand, have their fixed point in the neck; that those which fulfil the same purpose relatively to standing have theirs in the pelvis; that those which preserve the pelvis in equilibrium are attached to the bones of the thigh and leg; that those which prevent the falling of the femurs backwards, are inserted into the tibiæ; and that finally, those which maintain the tibiæ in the vertical position, have their fixed point in the feet. Thus all the efforts necessary for standing erect terminate at length in the feet; these must consequently present a resistance proportionate to the effort which they have to support. But the feet themselves have no other resistance than what is afforded by their weight; all that they present is afforded by the weight of the body which they support, so that the same cause which tends to make us fall, is exactly that which gives us security when standing.

The space between the feet, with the surface which they cover, is the base of support. The condition of equilibrium for standing erect is, that the vertical line drawn from the centre of gravity, shall fall upon one of the points of the base of support. Standing will be so much the more solid as this base is broader; in this respect, the breadth of the feet is far from being an object of indifference.

We know by observation, that our standing is as solid as possible, when the two feet, directed forwards, and placed upon two parallel lines, are separated by a space equal to the length of one of them. If the base of support is extended laterally, by separating the feet, standing becomes more solid in this direction, but less so from before backwards. The contrary occurs when one foot is placed before and the other behind.

The more the base of support is diminished, the less firm is our standing, and the greater muscular efforts are required to maintain it. This happens when we rise on the points of the feet. In this case, the feet touch the ground by the space comprised between the anterior extremity of the metatarsal bones and the extremity of the toes : this mode of standing fatigues, and cannot be long supported. Some persons, dancers, for instance, can rise even on the very points of the toes. This position may be conceived to present more difficulty. After all, whatever may be the part of the foot which touches the ground, it is always comprehended among the four parts which we pointed out at the beginning of this article, and we cannot be ignorant of the advantage of the packets of fatty cellular membrane which correspond to them.

Standing becomes very painful, or even impossible, if the feet rest upon a very narrow plane, a tight cord, for example.

We may say in general, that every cause which narrows the base of support, diminishes the solidity of standing, in proportion to the diminution of this base, as we may convince ourselves by examining individuals who have accidentally lost the toes by frost, or the anterior part of the foot by partial amputation of it, those who have one or two wooden legs, or those who are using stilts.

Standing upon two feet may occur in an infinite number of different positions of the body, as well as in the erect. The trunk may incline forwards, backwards, or laterally : the lower extremities may be variously bent.

If what has been said upon the erect posture is thoroughly understood, it will be easy to explain these attitudes.

Standing upon one Foot.

In some circumstances we stand on only one foot. This attitude is necessarily fatiguing; it requires a strong and continued action of the muscles which surround the articulation of the hip; from which action results the equilibrium of the pelvis upon one thigh; and as the body, and consequently the pelvis, incline from the leg which does not rest upon the ground, such a contraction as may support the trunk, is required from the muscles, the great, small, and middle glutei; the tensor of the fascia lata, gemelli, pyramidalis, obturators quadratus. We may here remark the use of the neck of the thigh, and the process called the geater trochanter: it is clear that they render the insertion of the muscles just mentioned less oblique, and that hence there is less loss of power in their contraction.

There is no occasion to add that when we stand on one foot, the base of support is represented by the surface of the ground covered by the foot, and that this posture is always less solid than that upon both feet, whatever may be their position. It becomes still more difficult and tottering, if, instead of resting on all the inferior surface of the foot, we touch the ground with one point only of it. It is scarcely possible to preserve such an attitude more than a few moments.

Kneeling.

The base of support in this position appears at first sight very extensive; and as the centre of gravity is depressed we may suppose that it is much more solid than standing upon both feet; but the breadth of the base which supports the weight of the body is far from being measured by all the surface of the two legs which touch the ground. The patella almost alone transmits the pressure to the ground; and the skin which covers it is strongly compressed, and not being supported by elastic fat, like the skin of the foot, it would be injured if this position were continued. It is to diminish the effects of this pressure, that we place a cushion under the patella when we intend to kneel for a length of time, or that we transmit a part of the weight of the body to the surface, by means of an intermediate body, upon which the upper part of the body rests. With the same view, i. e. to distribute the weight of the body over a greater surface, we bend the thighs backwards and rest them upon the legs and heels: then our posture becomes very solid and but slightly fatiguing, because the base of support is very broad, and the centre of gravity very near it.

Sitting.

We may sit in different manners: upon the ground, with the limbs forwards; upon a low seat, as a common seat, with the legs touching the ground; lastly, upon a high seat, with the legs not touching the ground, but hanging, and the back supported or not.

In every kind of sitting posture, where the back is not supported, and where the feet rest upon the ground, the weight of the trunk is transmitted to the ground by the pelvis, the breadth of which below is more considerable in man than in any animal. The base of support of the trunk becomes distinct from that of the bones of the lower extremities; it is represented by the extent which the thighs occupy upon the resisting plane which supports them. The more voluminous, and the better supplied with fat they are, the more solid will be our sitting posture.

When the back is not supported in sitting, a permanent contraction is required of the muscles of the trunk, to prevent it from falling forwards: and the posture fatigues, as we may remark after sitting a long while upon a stool. It is not so, when the back is supported by a solid body, as when we sit upon a chair; then the muscles which support the head are the only ones required to act, and which become fatigued. Long chairs are intended to prevent this inconvenience, as they support the back and head. Whatever may be the mode in which we sit, this posture may be preserved for a length of time, 1. because it requires the contraction of but few muscles; 2. because the base of support is broad, and the centre of gravity near; 3. because the thighs, in consequence of the thickness of their skin, and the quantity of their fat, are able to support a forcible and long continued pressure.

Of lying down.

Lying is the only posture which does not require any muscular effort; it is the attitude of repose, that of weak or sick persons, or those who are labouring under great prostration of strength: it can be continued a longer time than any other. The only organ which becomes fatigued in this position is the skin which corresponds with the base of support; the pressure of the weight of the body, although spread over a very large surface, and acting but little upon any particular part, is sufficient to produce at first uneasiness, and subsequently pain. And if the position remains long the same, as is the case in some diseases, the skin becomes excoriated and gangrenous, particularly in those parts which support the strongest pressure, as the back part of the pelvis, the great trochanters, &c.

To obviate the inconveniences of this pressure, we desire soft and elastic beds to lie upon, which may allow a more equal distribution of the pressure among all those parts of the skin which correspond with the base of support.

Of Motions.

We observe two kinds of motion: the first are intended to change the reciprocal position of different parts of the body; the second to change the relation of the body with the ground: the former are called *partial,* the second *locomotive.*

Of partial Motions.

Most partial motions constitute an inherent part of the functions: many have been already described; others will be so in their turn. We shall speak at present of those only which admit of separation from the history of the functions. We propose speaking in succession of those of the face, head, trunk, superior extremities, and, lastly, of the inferior extremities.

Partial Motions of the Face.

It is easy to remark, that the motions have two distinct objects: the first to contribute to the sensations of sight, smell and taste, and also to take hold of our food, to perform mastication, deglutition, voice and speech; the second, to express our intellectual acts and the passions.

Independently of the motions of the face, which contribute to vision, smell, taste, voice, speech, &c. and which we have already mentioned, and of those which serve for taking hold of our food, for mastication, deglutition, &c. which will be mentioned hereafter in their proper places; the muscles of the face determine in it certain motions intended to express intellectual acts, the different dispositions of the mind, instinctive desires and passions. Pleasure and pain, joy and sorrow, desires and fear, anger, love, &c. have each a characteristic social expression. Painful or sad affections however, and violent desires, are in general marked by a contraction of the countenance; the eyebrows are knitted, the mouth contracted, its ends lowered; in pleasant and gay affections, on the contrary, in agreeable sensations, when our desires are satisfied, the countenance expands, the eyebrows rise, the eyelids separate, and the angles of the mouth are drawn upwards and outwards, which produces smiling. Persons in whom the different expressions are most marked, or who in common language have a striking physiognomy, are persons commonly of lively sensibility. The contrary is usually the case with persons whose countenance is immoveable, or presents but slightly marked expressions. When a certain disposition of mind, or a passion, are continued for a length of time, the muscles which are habitually contracted to express it, acquire more size, and assume a manifest preponderance over the rest of the muscles of the face; then the physiognomy preserves the expression of the passion, even when it is not felt, or long after it has ceased. The consideration of physiognomy is really a very good means of judging of the character or the habitual passions of an individual.

The colour or paleness of the skin of the face is likewise a powerful means of expression in regard to the intellect and the passions; we shall treat of it hereafter in the article, *Capillary Circulation.*

Motions of the Head upon the vertebral Column.

The head may be inclined forwards, backwards, or sidewise: it can also execute rotatory motions to the right or left. If the motions by which the head is inclined forwards or backward, or laterally, are rather extensive, they occur in the articulation of the head with the first cervical vertebra; if they are more extensive, all the vertebræ of the neck share in them. Its rotatory motions occur essentially in the articulation of the atlas and the axis, which articulation is evidently intended for this use. These different motions, which are often indeed combined, are determined by the successive or simultaneous contraction of the muscles which run from the chest and neck to the head.

It is easy to see that the motions of the head favour sight, hearing, and smell; they are also useful in the production of the different tones of the voice by permitting the elongation or shortening of the trachea and vocal tube. These motions serve also as expressions of the mind: approbation, consent, refusal, are marked by certain motions of the head upon the neck: some passions also induce particular motions or attitudes of the head.

Motions of the Trunk.

We shall speak in this article of those motions only which are peculiar to the vertebral column; those peculiar to the chest, abdomen, and pelvis, will be spoken of elsewhere.

Flexion, extension, lateral inclination, circumduction and rotation, are the motions performed by the vertebral column as a whole, by each region of it, and even by every individual vertebra.

These different motions take place in the intervertebral fibro-cartilage; they are the more easy and extensive, in proportion as these fibro-cartilages are thicker and broader: hence the motions of the lumbar and cervical portions of the vertebral column are evidently more free and considerable than those of the dorsal portion. Every body is aware that the cervical fibro-cartilages, and especially the lumbar, are proportionably thicker than the dorsal.

In the motions of flexion, whether forwards, backwards, or laterally, the fibro-cartilages are compressed in the direction of the flexion, and elongated in the opposite direction. The thickest part experiences the greatest compression. This is one reason why flexion forwards is more extensive than any other motion of the vertebral column.

In rotation, the whole of these intervertebral bodies experiences an elongation in the direction of the plates which compose them. The centre of these bodies is a soft and nearly fluid matter; the circumference alone offers great resistance; and yet, in the motions by which the vertebræ approximate, this circumference yields sufficiently to form a sort of pad between the two bones.

The disposition of the articular surfaces of the vertebræ, is one circumstance which influences still more the extent and mode of the reciprocal motions of the vertebræ.

When we contemplate the motions of the vertebral column as a whole, it represents a lever of the third kind, whose point of support is in the articulation of the fifth lumbar vertebra with the sacrum; the power, in the muscles inserted into the vertebræ on the sides; and the resistance in the weight of the head, of the soft parts of the neck, chest, and partly of the abdomen. Each vertebra, taken separately, on the contrary, represents a lever of the first kind, whose point of support is in the middle, upon the vertebra placed immediately below. The power and the resistance are alternately before and behind, or on the right or left side, at the extremities of the transverse processes.

The motions of the vertebral column are frequently accompanied by those of the pelvis upon the thighs; they in this case appear to have a far greater extent than they have in reality.

The motions of the vertebral column are intended most frequently to favour those of the superior and inferior extremities, and to render the various attitudes or positions which the body assumes as a whole, less fatiguing or more supportable.

Motions of the superior Extremities.

As the superior extremities are the principal organs by which we, directly or indirectly, produce changes for our own purposes in surrounding bodies, they must combine extreme mobility with a pretty great degree of solidity. We in fact observe in the limbs, that the long bones are very long, and that they are slender; the short bones are of no great size; neither are very heavy; the articular surfaces are of small dimensions; the muscles very numerous, and their fibres in many instances of great length. The bones almost always represent levers of the third kind, which are favourable as we have already remarked, to extent and rapidity of motion. And, whether we contemplate the superior extremities in their general motions relative to the trunk, or in their partial motions, we readily discover that they unite quickness and variety to a high degree of extent of motion.

The solidity of these limbs is not less worthy of remark. In a number of cases they have to support considerable efforts, as when we rest upon a stick, when we fall forwards and the hands receive the shock, &c.

We cannot enter into the details of this wonderful mechanism, but refer to the *Anatomie descriptive* of Bichat, whose genius was very successfully exerted in describing animal mechanism.

The superior extremities are essentially useful in the exercise of touch, of which the hand is the principal organ: they assist the action of the other senses, by approximating or withdrawing bodies, or by placing them in circumstances favourable for their being acted upon by the senses. Their motions powerfully contribute to the expression of the acts of intellect and instinct. Gestures form a true kind of language, which is susceptible of acquiring great perfection, when circumstances render it of great utility, as happens in deaf and dumb persons. In this case the gestures point out not merely sentiments, wants, and passions, but the slightest shades of the faculty of thought.

The superior extremities are often useful in the different attitudes of the body. In some cases they transmit part of its weight to the ground, as when we lean upon a stick, when we are upon our hands and knees, when we rest upon our elbows while sitting on an horizontal plane, &c.

They may also secure solidity of standing by being carried in the direction opposite to that in which the body is inclined to fall by its weight. We shall presently see that they are not without their use in the different modes of progression.

Motions of the inferior Extremities.

Although an analogy evidently exists between the superior and inferior extremities, the latter are as evidently constructed more for solidity and extent than the former for rapidity and variety of motion; this disposition was very necessary, for the inferior extremities seldom move without supporting the weight of the body, and are the chief agents in locomotion.

When, however, we give any modification to external bodies by the lower extremities, they move independently of the trunk; thus when we change the form of a body by pressing it with the foot, or when we displace it by a kick, when we feel with the foot, as for example, in examining the ground upon which we think of treading, &c. the various motions which occur, are obviously unconnected with any motion of the trunk.

We shall not at present describe particularly the different general or partial motions of the extremities, but shall speak concisely only of the various modes of locomotion,

i. e. of the motions by which the body is transported from one part to another, and which are *walking*, *running*, *leaping*, and *swimming*.

Motions of Locomotion.

Of Walking.

The action of walking is not performed always in the same manner. We walk forwards, backwards, sidewise, and in directions intermediate to these; we walk on an ascent or a descent, on a solid or a moveable surface; our walk varies also in the size or rapidity of our steps, &c.

Whatever may be the mode of walking, it necessarily consists of a succession of steps; so that the description of walking is only the description of our manner of executing a succession of steps. We must therefore describe a step and its principal modifications.

Supposing a person erect with his two feet placed side by side, and going to walk on an horizontal surface by steps of the usual size and quickness, he must bend one of his thighs upon the pelvis, and the leg upon the thigh, that he may remove his foot from the ground by the general shortening of the limb. The flexion of the thigh causes the whole limb to advance forwards: then the limb rests upon the ground; first the heel comes down, and all the lower surface of the foot in succession. While this motion is proceeding, the pelvis experiences an horizontal rotatory motion upon the head of the thigh belonging to the limb that remains motionless. The object of this rotation of the head of the thigh is, 1. to carry forward the whole of the limb which is removed from the ground; 2. to carry forward also the side of the body corresponding to the limb which moves, while the side corresponding to the motionless limb remains behind. These two effects are scarcely sensible in small steps; they are very well marked in common steps, but much more in larger ones. Hitherto there has been no progression, the base of support only has been modified. To complete the step, the limb which remains behind must approach, either coming in the same line, or passing beyond the limb which has advanced. For this purpose, the foot behind must be removed from the ground, successively from heel to point by a rotatory motion, the centre of which is in the articulation of the metatarsal bones with the phalanges, so that at the end of this motion, the foot touches the ground merely by the latter. From this motion of the foot results an elongation of the limb, the effect of which is to carry forwards the corresponding side, and to rotate the pelvis upon the head of the thigh of the limb first advanced. When this motion is once produced, the limb bends, the knee is directed forwards, the foot detached from the ground; then the whole limb executes the same motions which were previously executed by the opposite limb.

By the succession of these motions of the lower extremities and of the trunk, walking is produced, in which we see that the heads of the thighs are alternately the fixed points upon which the pelvis turns as upon a pivot, describing arcs of a circle more extensive in proportion as the steps are larger.

To walk in a straight line, the arcs of a circle, which are described by the pelvis, and the extension of the limbs when carried forwards, must be equal, otherwise, we shall deviate from a straight line, and the body will be directed from the side opposite to the limb whose motions are the most extensive; and as it is difficult to make the two limbs perform in succession exactly the same extent of motion, we have always a tendency to deviate, and should in fact deviate, unless our sight warned us of the necessity of correcting this deviation. We may convince ourselves of this fact by walking a little way with our eyes shut.

Having described the mechanism of walking forwards, it will not be difficult to give an idea of walking backwards, or sidewise.

When we step back, one of the thighs is bent upon the pelvis, and at the same time the leg is bent upon the thigh : the extension of the thigh upon the pelvis follows, and the whole limb is carried backwards ; then the leg is extended upon the thigh and the point of the foot, and soon the whole of the inferior surface touches the ground. The moment the foot directed backwards is applied to the ground, the foot which remained before, rises on the point; the corresponding limb is elongated; the pelvis, pushed backwards, rotates upon the thigh of the limb carried backwards ; the leg which is before, entirely leaves the ground, and is itself carried backwards to furnish a fixed point for another rotation of the pelvis, to be produced by the opposite limb.

When we wish to perform a lateral step, we first slightly bend one of the thighs upon the pelvis, to detach the foot from the ground ; we next move the whole limb laterally from the other, and then rest it upon the ground ; we immediately approximate the other limb to that which was originally displaced, and so continue. In this case there can be no rotation of the pelvis upon the thighs.

If we walk upon an ascending surface, we know that the fatigue is greater : and because in this kind of progression the flexion of the limb first carried forwards must be greater, and the limb which remains behind has not only to rotate upon the pelvis, but likewise to raise the whole weight of the body, for the purpose of transporting it upon the limb which is before; the contraction of the anterior muscles of the limb now before, is the chief cause of this transport of the body; and these muscles are much fatigued in the action of ascending a stair-case, or any other rising plane.

For an opposite reason, walking upon a descending surface is also more uneasy than upon an horizontal one. Here, the posterior muscles of the trunk have to contract forcibly, to prevent the body from falling forwards.

All these modes of progression which we have now rapidly described, require easy motions of all the joints of the lower extremities, and an equal action of each of the limbs: the least difficulty in the play of the articular surfaces, the least difference in the length or form of the bones of the two limbs, as well as in the force of the contraction of the muscle, necessarily produce sensible alterations in our progression, and render it more or less difficult.

Of Leaping.

If we attentively examine this motion, we shall find that the body becomes a projectile, and obeys all the laws of projectiles.

Leaping may be directly upwards, forwards, backwards, or sidewise, &c.; but in all these cases, the preceding and accompanying phenomena must be considered. Every kind of leaping requires the previous flexion of one or more articulations of the trunk and lower extremities; the sudden extension of the bent articulations is the immediate cause of leaping.

Let us suppose a vertical leap performed in the most usual manner: the head is a little inclined upon the neck; the vertebral column bent forward; the pelvis is bent upon the thigh, the thigh upon the leg, and the leg upon the foot; the heel generally presses but slightly upon the ground, or quits it altogether. To this state of general flexion suddenly succeeds an extension of all the bent articulations; and the different parts of the body are rapidly raised with a force which surpasses their weight in variable degrees: thus the head and thorax are directed upwards by the extension and recovery of the vertebral column; the trunk altogether receives the same direction by the extension of the pelvis upon the thighs; the thighs by rising rapidly act in the same way upon the pelvis, and the legs in their turn push upwards the thighs. From all these united efforts results a projecting force, by which all the body is impelled upwards, and higher in proportion as this force surpasses its weight; after which it falls upon the ground with the same phenomena as any other body falling in obedience to its weight.

In the general spring which produces leaping, the muscular action is not throughout of the same intensity; it must be evidently greater where the weight to be elevated is heavier: hence the muscles which extend the leg upon the foot exert most energy, because they have to raise the whole weight of the body and give it an impulse exceeding its weight. These muscles are also the most favourably disposed; they are extremely strong, are inserted perpendicularly to the lever which they move (the os calcis) and act by a very long arm of the lever.

We must remark, that a leap upwards does not result from a direct impulse, but from opposite impulses of the body and lower extremities at the moment of leaping. The recovery of the head, the vertebral column and pelvis, carry the head as much backwards as upwards; the rotation of the thighs upon the tibiæ, carries the trunk as much forwards as upwards. It is the contrary with the motion of the leg, which has a tendency to direct the trunk upwards and backwards; when the leap is vertical, the efforts which carry the trunk forwards or backwards destroy each other; the effort upwards alone has its effect.

In the leap forwards, the rotation of the thigh exceeds the impulses backward, and the body is carried in that direction; if the leap is backwards, the extension of the vertebral column and of the tibia upon the foot, has the ascendant, &c.

The length of the bones of the lower extremities is favourable to the extent of leaping; the leap forwards by which we pass over larger spaces than by any other mode of leaping, owes its advantage to the length of the thigh.

Sometimes we run a greater or smaller distance before leaping; we take a spring as we say: the impulse acquired by the body in this preliminary run is added to that which is received at the moment of leaping, by which the leap acquires more extent.

The arms are not without their use in leaping: they are nearer the body when the joints are bent; and separate, on the contrary, the moment the body leaves the ground. The resistance offered by them to the muscles which raise them, gives these muscles an opportunity of drawing the trunk upwards, which contributes to the production of the leap. The arms fulfil this purpose so much the better, as they present a certain degree of resistance to the contraction of the muscles which raise them. The ancients made this remark: they carried in each hand weights called Halteres, when they were going to leap. By previously balancing the arm, we may also favour the horizontal leap, by giving an impulse forwards or backwards to the upper part of the trunk.

One limb alone is sufficient for leaping, as happens when we hop; but it is obvious, that this mode of leaping is, of necessity, less extensive than when both limbs are employed. Sometimes we leap with the two feet near, and parallel, or *close-footed;* sometimes one foot advances during the projection of the body: this is then the foot which receives the weight of the body, the moment we come to the ground.

No kind of impulse can be communicated to the body by the plane which supports it at the moment of the leap, unless this plane, being very elastic, joins its reaction to the effort of the muscles which determine the projectile motion of the body. Most frequently, the only use of the ground in leaping, is to resist the pressure exerted upon it by the foot. Every one knows, that it is nearly impossible to leap when the ground is soft, and yields to the pressure of the feet.

We owe the true theory of leaping to the celebrated *Barthez,* of Montpellier; before him, we had but very imperfect ideas of the explanation of this phenomenon. There is no relation between the spring of an elastic curve and leaping.

Of Running.

Running results from the combination of stepping and leaping, or rather consists of a succession of leaps performed alternately by one limb, while the other is carried forwards or backwards, to be applied to the ground and produce the leap as soon as the first has had time to be carried backwards or forwards, accordingly as we run in one or the other direction. We may run more or less rapidly; but in running there is always an instant during which the body is suspended in the air, in consequence of the impulse communicated to it by the limb which remains behind, if we run forwards. This character distinguishes running from quick walking, in which the foot carried forwards touches the ground before that which is behind has left it.

For the reasons pointed out under the head *of walking*, the least fatiguing mode of running is upon an horizontal plane; running upon an inclined plane, either ascending or descending, is always more or less uneasy, and cannot be long continued.

We shall not describe, even concisely, the numerous modifications of progression, such as climbing, walking on crutches, stilts, or artificial legs: nor the various motions comprehended under the art of dancing, whether in the common mode, or upon a tight or slack rope; nor the motions performed by leapers, nor those of fencing, riding on horseback, or of different professions or occupations. Considerations of this kind would no doubt be very important, but they can form a part of a complete treatise only of animal mechanics; a work still wanted, notwithstanding those of Borelli and Barthez. We shall merely say a few words upon *swimming*.

Of Swimming.

The body of man is specifically heavier than water, consequently when abandoned in the midst of a considerable mass of this fluid, it will have a tendency to sink to the bottom: this motion will be the more easy in proportion as the surface by which it strikes against the water is less extensive. If, for instance, the body is placed vertically, the feet below and the head above, it will come to the bottom much sooner, than if the body was placed horizontal on the surface of the fluid. Some persons, however, have this power of rendering themselves specifically lighter than water, and can consequently remain upon its surface without any effort. Their method consists in drawing a large quantity of air into the lungs, the lightness of which counterbalances the tendency of the body to sink in this fluid.

Swimmers do not keep up or move on the surface of water, by this method, but by motions of their limbs. The object of the motions of swimming is to support the body on the surface, or to cause its progression. Whatever may be the intention, a swimmer must act upon the water in such a way that it may present a sufficient resistance to support the body, or permit its displacement: with this view he has only to strike it faster than it can escape, and to make his hands or feet act rapidly upon many different points, because the resistance is greater as the mass of water displaced is more considerable. The motions of the inferior extremities, in the most common mode of swiming, *la brassée,* are very analogous to the motions of leaping.

There are many modes of swimming; but in all it is necessary to strike or press the water faster than it can recede.

A man cannot fly; his weight, compared with that of the air, is too considerable, and the force exerted by the contraction of his muscles infinitely too weak. Every attempt made to support a man in the air by machines more or less analogous to the wings of birds, have been nearly equally fruitless.

Of the Attitudes and Motions at different Ages.

From the embryo state to the eighteenth or twentieth year, the bones are constantly changing, in form, size, volume, &c.; consequently during the whole period of ossification, the attitudes and motions must experience changes corresponding to those of the skeleton. We have already seen, that the muscles and muscular contraction are also modified by the state of the fœtus, of infancy, youth, &c.; the same circumstances have great influence upon the motions. The increase of the length of the bones is commonly terminated at the twentieth or twenty-second year; but they continue to increase in thickness, even beyond the adult period; then every kind of increase ceases, and the changes which occur to the bones, till the period of decrepit old age, influence only their nutrition and chemical composition.

The position of the fœtus in the uterus depends upon circumstances at present but little known: most frequently its head is downwards, probably on account of its greater weight; but why should the occiput almost always correspond to that part of the pelvis which is above the left acetabulum? Why does the fœtus sometimes lie very differently; for instance, with its thighs below, directed to the right or left side? We cannot tell.

The thighs of the fœtus are bent upon the abdomen; the legs are applied to the thighs, the arms crossed on the fore part of the trunk, and its head most frequently bent upon the chest; so that the fœtus occupies the smallest space possible. This position does not depend upon a continued muscular contraction, but is the effect of the tendency which the muscles have to shorten; at a more advanced age, we often take the same position, when we wish to put all the muscles in a state of repose.

Four months from conception, the fœtus begins to perform partial motions, and perhaps some slight motions which cause a change of place in the whole body. These motions are irregular, occur at variable distances, last till the end of pregnancy, and are frequently performed by the lower extremities, if we may judge by the points in which they are felt. They cannot be supposed to depend upon the will, for understanding does not yet exist, and acephalous fœtuses, i. e. those without brain, present them like well-formed fœtuses.

The new-born child cannot itself take any posture, but retains that which is given to it; however, we know that lying upon the back is the situation which it prefers, and which, in fact, most corresponds with the weakness of its muscular system. Its upper and lower extremities present pretty strong motions; its physiognomy is without expression.

In about two or three months, the child changes its attitude, when left to itself: it lies upon its side or belly, it turns its head; the motions of its limbs are more multiplied and more energetic; it seizes bodies more forcibly which are offered to it, and carries them to its mouth; when sucking, it strongly compresses its mother's breast, &c.; but it cannot stand or sit. Of this the following are the principal reasons: The head is proportionally very voluminous and heavy; it falls forwards, not being supported by a proper muscular effort; the weight of the pectoral, and especially of the abdominal viscera, is enormous, the vertebral column presenting a curve which is convex behind. The posterior muscles of the trunk are too weak to resist the disposition which the vertebral column has to incline forwards; but besides, the spinous processes do not exist, so that the arms of the lever by which they act is very short, a circumstance unfavourable to their action. The pelvis, very small and inclined very much forwards, scarcely sustains the weight of the abdominal viscera. The lower extremities are but little developed, and their muscles are too weak to balance for a moment the motion of the trunk forwards. Every kind of erect position is therefore impossible.

The infant, however, by means of its superior and inferior extremities can soon move itself a little from place to place; and because this mode of progression is somewhat analogous to that of certain animals, some sophists have maintained that man was naturally a quadruped, and that standing upon two feet was an acquisition dependant upon social life. For this idea to be at all founded, the organs of motion in the adult should be disposed like those of the child: now we have seen that the case is very different.

Towards the close of the first year, sometimes at the commencement of the second, sooner or later, from the effect of the developement of the bones, muscles, &c. by the proportional diminution of the volume and weight of the head, the abdominal viscera, &c. the child becomes able to stand, but cannot yet walk; soon it acquires this power, by taking hold of objects which are near it; at length it walks alone, but in a totteting manner, and the least cause throws it down. Stepping is at first its only kind of locomotion: much time commonly elapses before it can run, and especially before it can leap to any extent; but when it is once established in progressive motion, it is in continual agitation; it acquires agility and address; it contracts a taste for different sports, which, almost all, especially in boys, serve to exercise the organs of locomotion and understanding.

In physiological respects, the sports of children are well worthy of remark. If studied with attention, they will be found the model of the actions of the adult man; the same resemblance may be established in the sports of animals, which likewise are in some measure the repetition of the actions which they will afterwards be called upon to execute.

In the sports of children, we must not confound those which are purely instinctive with those which result from imitation.

From youth to the adult period, and even beyond it, all the phenomena of attitude and motion are in perfection; they gain energy only with age; but in old age, they undergo a remarkable alteration, which arises from the weakened state of muscular contraction: as this no longer takes place without a certain degree of difficulty, as it is trembling, the attitudes and motions must feel the effects of it. The old man, whether he walks or stands, is commonly bent forwards; the pelvis bends upon the thighs, they upon the legs; and lastly the legs are inclined forwards upon the feet. This general state of demiflexion depends upon the weakened power of the muscles, which have no longer sufficient energy to preserve the uprightness of the body.

The old man also finds great advantage in the use of a stick, by means of which he augments the base of support, and transmits directly to the ground the weight of the upper part of the body.

In decrepitude, the motions become extremely difficult, and sometimes even altogether impossible.

Relation of the Sensations with the Attitudes and Motions.

The sensations influence the attitudes and motions, and these again have a manifest influence upon the sensations.

Sight contributes powerfully to the firmness of most of our attitudes: by it we judge of the position of our body, comparing it with that of surrounding objects. Thus when we are deprived of this means of judging of our equilibrium, as when we are at the top of an edifice, or upon any elevated spot, where we are surrounded only by air, we stand insecurely upon our two feet, and perhaps are unable to continue in this attitude.

The utility of sight is still greater if the base of support is very narrow. A rope-dancer cannot keep himself upright, unless his sight continually informs him of the position which he must keep, that the perpendicular drawn through the centre of gravity may pass through the base of support.

Whatever may be in general our attitude, it is not very firm unless we employ our eyes. This fact may be proved by observing the standing and attitudes of a blind man.

If sight is of so much assistance to attitudes, it must be much more so in the different kinds of partial or locomotive movements. In fact, sight enlightens and favours our motions: it gives them the necessary precision and rapidity, and in almost every case directs them. When a brisk and adroit man is blind-folded, he immediately loses almost all his advantages; his walk is timid, especially if he is not perfectly acquainted with the place; all his motions have the same character. The same phenomena occur in blind persons, who are easily recognized by the least movements which they make, unless very familiar to them. The absence of sight disposes to inability; the use of this sense, on the contrary, excites to motion; every body knows that we are strongly inclined to seize and touch objects the first time we see them.

The consideration of the relations between sight and motion gives us occasion to remark, that those motions which are intended to express our intellectual and instinctive acts, and which may be included under the generic name of *gestures*, may be divided into those which are intimately connected with the organization, and consequently exist always in man, in every condition, and into those which arise in the social state and become perfect with it.

The first are intended to express the most simple wants; the strong internal sensations, as joy, grief, fear, &c. as well as the animal passions; they are to the motions, what cry is to the voice. They are observed in the idiot, the savage, and the blind from birth, as well and as fully as in the civilized man enjoying all his physical and moral advantages.

Independently of the physical properties which every part of the body presents, there are many which offer either continually, or at more or less distant intervals, a phenomenon termed *vital action*. For example, the liver continually forms a fluid called *bile*, in virtue of a power peculiar to it; the same may be said of the kidney with respect to the urine. The voluntary muscles, under certain conditions, harden and change their form; in a word, contract. This also is an instance of a vital action. These vital actions are very important to the life of man and animals, and they particularly demand the attention of the physiologist.

Vital action depends evidently upon nutrition, and nutrition again is influenced by vital action. Thus an organ which ceases to be nourished, loses at the same time the faculty of acting; thus organs whose action is the most frequently repeated, have a more active nutrition : on the contrary, those which act less have evidently a sluggish nutritive movement.

The mechanism of vital action is unknown. There occurs in the organ which acts an insensible molecular movement as inexplicable as the nutritive movement. No vital action, however simple, is an exception in this respect.

All the phenomena of life may be thus ultimately referred to nutrition and vital action; but the molecular movements which constitute these two phenomena are not sensible, and we must not direct our attention to them : we can study their last results only, i. e. the physical properties of organs, and the sensible effects of the vital actions, and examine how they both concur to general life.

The gestures of the second kind can exist only in the social state; they suppose sight and intelligence, and are not observed in those who are blind from birth, in the idiot, nor in those who have always lived alone.

They may be termed *acquired or social gestures*, from their analogy to acquired voice. It is very probable that in giving sight to a person blind from birth, you would at the same time give the gestures in question.

It may be said that the gestures of persons born blind are absolutely of the same description as the voice of a person born deaf. These two phenomena mutually supply each other: the deaf and dumb person is continually employing gestures, and carries them to a high degree of perfection; the voice, on the contrary, is the only means of expression enjoyed by the blind person: hence his taste for singing, and speaking, and the accent which he gives to his voice.

The ear is not without its influence upon motions; this sense sometimes contributes with sight to direct and especially to measure them, to make them return at equal intervals, and to produce a certain number of them in a given time, as in dances and military marches. It is an old observation, that measured movements, executed to the sound of music or to the noise of the tamborine, are much less fatiguing than others: it is because they are regular, because every muscle contracts and relaxes alternately, and because the period of repose equals the period of action. We must add, that music and even noise excites to motion.

The relation of smell and taste with the attitudes and motions is too important not to be mentioned. As to touch, as muscular contraction is inherent in it, as sensation could not take place without muscular action, it is easy to see that it is closely connected with all the phenomena which depend upon the contraction of muscles.

The internal sensations have not less influence upon the various attitudes and motions of the body than the external. Who cannot discover a man with a strong pain or any other kind of sensation, by his walk or posture? We are able in a certain degree even to determine the particular seat of the painful affection by the position or motion of the patient. A violent colic is known to all to dispose us to bend the chest upon the pelvis and apply the hands to the abdomen; that a strong stitch in the side disposes us to lie upon the side which is painful; that the presence of a stone in the bladder causes the patient to assume particular attitudes.

We have seen the influence of the sensations upon our attitudes and motions. The latter in the same way re-act upon the action of the senses; the various attitudes are favourable or unfavourable to the developement of the external sensations; the motions are much concerned in it. There are particular partial motions peculiar to each sense, and favourable to its action; besides, almost all the senses have particular muscles which form an essential part of the sensitive system, as is seen in the eye, the ear, the hand, &c.

Relations of the Attitudes and Motions with the Will.

The attitudes and motions just described are generally called *voluntary*, because, it is said, they are under the immediate influence of the will. This assertion is true in a certain point of view, but not in others: we must therefore explain ourselves on this point.

After a determination of the will, a motion is produced, and no doubt in consequence of it; but all the phenomena which occur in the production of a motion are not under the power of the will. I can move my arm or hand, but am unable to contract the muscles of these parts separately or altogether, unless I have an idea of the motion to be produced. It is the same with the contraction of all the muscles which are considered under the influence of the will. How should we set about contracting the external obturator, or any other muscle separately, which does not produce by itself a determinate motion? The thing would be impossible.

We may affirm that the determining cause of motion is the will; but the production of the muscular contraction necessary for motion does not depend upon the will; it is purely instinctive.

After these considerations it would be right to conclude that will and the action of the brain, which directly produce the contraction of muscles, are two distinct phenomena; but the direct experiments of modern physiologists, and particularly of Le Gallois, have put this truth in the strongest light. His experiments have demonstrated that the will is more particularly seated in the cerebrum and cerebellum. The direct cause of motion appears, on the contrary, seated in the spinal marrow. If the spinal marrow is separated from the rest of the brain by a section behind the occipital bone, the will is prevented from determining and directing the motions; but the latter are not the less produced; it is true that as soon as the separation is made they become very irregular in extent, rapidity, duration, direction, &c.

If the action of the brain which produces muscular contraction is a phenomenon distinct from will, it may be readily conceived why, in some cases, motions are not produced, although commanded by the will, and why, in some opposite circumstances, very extensive and strong motions are developed without any connection with the will, as we frequently see in many diseases. For the same reason it may be conceived why it is very difficult, sometimes even impossible, to take an attitude which is new to us, and to execute a motion for the first time; why all the arts, as dancing, fencing, &c., which depend upon rapidity and precision of motion, are acquired by long practice only; and why, finally, we often execute a motion more perfectly if we turn our attention from it, than if we direct our attention fully upon it.*

Relations of the Attitudes with Instinct and the Passions.

We have just seen that most of what are called *voluntary motions* and *attitudes,* are under the dominion of instinct: very many attitudes and motions, partial and general, depend essentially upon it.

All the instinctive feelings attached essentially to organization, as sorrow, fear, joy, hunger, thirst, when carried to a certain degree, have attitudes and motions which are peculiar to them and demonstrate their existence; it is the same with the natural passions and all the instinctive phenomena which are developed in the social state.

Many passions excite to motion, and greatly increase the intensity of muscular power, as is seen in excessive joy, anger, certain instances of fear, &c. Other passions stupify and render every kind of motion impossible, as violent grief, a certain degree of terror; joy frequently produces the same effect; hence the art of pantomime is employed with success in painting violent passions.

Relations of the Motions with the Voice.

The relations of the motions with the voice are intimate, and must be so, because these two kinds of phenomena are the immediate effect of muscular contraction; with this difference, that with respect to the

* This doctrine has just been again confirmed by the experiments of an English Physician, A. Wilson Philip. See the *Philosophical Transactions*, 1815.

voice we hear the effect, and see it with respect to the motions.

There are motions essentially attached to organizations; the same is the case with crying.

One kind of voice is acquired in the social state; many motions are acquired in the same manner.

The voice and motions are united for the production of speech. These two phenomena are the principal and almost only means of expression: they mutually assist and supply each other; a man who expresses himself with difficulty makes much use of gestures; it is the contrary with persons whose elocution is easy. In violent passions, the two modes of expression are combined; we seldom express a strong feeling without joining gesture with speech.

The modifications which the voice and motions undergo by age must have been remarked to be very analogous: the same would be observed of the changes experienced from sex, temperament, habit, &c.

With these considerations we terminate our description of the functions of relation. The common character of these functions is that of being periodically suspended, or, in other terms, of being plunged at intervals into a state of sleep. It might therefore appear right that the history of sleep should immediately follow that of the functions of relation; but as the nutritive and generative functions are also very much influenced by sleep, we prefer postponing the study of it till we have finished the description of these funcions: which will be in the following volume.

END OF VOL. I.

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