AN

ELEMENTARY COMPENDIUM

OF

PHYSIOLOGY:

FOR THE USE OF STUDENTS.

By F. MAGENDIE, M. D.

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TRANSLATED FROM THE FRENCH,

WITH COPIOUS NOTES AND ILLUSTRATIONS,

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REVISED AND CORRECTED BY A PHYSICIAN OF PHILADELPHIA.

WITH AN APPENDIX.

PHILADELPHIA:

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EASTERN DISTRICT OF PENNSYLVANIA, TO WIT:

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"An Elementary Compendium of Physiology; for the use of Students. By F. "MAGENDIE, M. D., Member of the Institute of France, Physician of the Central "Chamber of Admission to the Hospitals and Municipal Charities of Paris; Pro-"fessor of Anatomy, Physiology, and Semeiotics; Member of the Philomathic "and Medical Society of Emulation of Paris; of the Medical Societies of Phila-"delphia, Stockholm, Wilna, the University of Dublin; of the Philosophical So-"ciety of London, the Wetteravian Society of Hanau, &c., &c. Translated from "the French, with copious Notes and Illustrations, by E. MILLIGAN, M. D. Licen-"tiate of the Royal College of Physicians, Extraordinary Member of the Royal "Medical Society, and Lecturer on Physiology and Therapeutics, Edinburgh. "Revised and corrected by a Physician of Philadelphia. With an Appendix."

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D. CALDWELL, *Clerk of the Eastern District of Pennsylvania.*

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TO

ANDREW DUNCAN, Jun. M.D. F.R.S.

PROFESSOR OF MATERIA MEDICA IN THE UNIVERSITY OF EDINBURGH,
&c., &c., &c.,

THE FOLLOWING TRANSLATION,

AS A JUST TRIBUTE TO HIS EXERTIONS AND EXAMPLE,

IN TRANSFUSING THE IMPROVEMENTS OF THE CONTINENT INTO THE

MEDICAL SCIENCE OF HIS COUNTRY,

AND IN CULTIVATING, WITH UNREMITTING ZEAL, THE LATTER,

IN ALL ITS VARIOUS DEPARTMENTS;

AND

AS A SMALL TESTIMONY

OF PERSONAL ESTEEM FOR HIS EMINENT TALENTS

AND LIBERAL MANNERS,

IS RESPECTFULLY INSCRIBED

BY

THE TRANSLATOR.

THE TRANSLATOR'S PREFACE.

AFTER the favourable reception which the original of this work has met with from the public, and the honours so deservedly heaped on its author by the learned in all parts of Europe, it cannot, surely, be necessary, in this place, to insist on the merits of either. The book has been so often pronouneed, by the ablest judges, to be the first work on Physiology; and its author is so confessedly the most eminent physiologist of the present day, that the task of encomium is quite superseded. The fame of Bichât is chiefly founded on his general anatomy; but our author's researches embrace nearly the whole range of Physiological science, and few of its departments have not rewarded his labours by some interesting discovery. Of most of these he has delivered a succinct account in the present manual: and though its plan necessarily excludes lengthy discussion, and that parade of quotations, which so often display only the knowledge of other writers, and the pedantry of the citator, it cannot be read without perceiving that M. MAGENDIE has stored his mind with extensive reading, and considered, with much judicious reflection, the sentiments of other physiologists: and, in short, that he has omitted little that properly belongs to Physiology.

As the Translator's object was merely to present the British student with a version of this valuable COMPENDIUM in his own language, to illustrate obscure passages, and to supply any important particulars that may have happened to escape the attention of his author, he has not found it necessary to overshadow the original with notes. Still, where it appeared necessary, he has taken care to supply them, as nearly as possible in the brief manner of the text. The reader will find that the references are mostly confined to accessible works, and occur as seldom as the nature of the subject would admit; it being the business of the student of Physiology to acquire a knowledge of facts rather than names.

Respecting some few particulars, M. Magendie has probably been mistaken. In these instances, the Translator has endeavoured to lay the substance of the argument on both sides before the reader; or to point out, what seemed to him, the source of error. Satisfied with securing the reader from mistake, he has nowhere sought to introduce indecorous controversies with his author; having little desire of acquiring fame from this unnatural species of superfetation, in which, however fashionable, the new comer only finds a parasitical existence at the expense of its predecessor.

The articles supplied in the notes are what appeared to be of an important character. The reader will find that they embrace many of the most interesting points of Physiology, together with the opinions of the more eminent cultivators of the science who figure in the present day; several revived theories restored to their original inventors, and now and then some curious speculations not occurring in our elementary works.

Among the necessarily miscellaneous articles thus added to the text, are discussions on the Tissues of Bichat, Bichat's Doctrine of the double Life, On the Secretions, The Anatomy of the Eye, The Yellow Spot of Soemmering, Dr. Knox's Discoveries, Ciliary Processes, Canal of Petit, Voice, Muscular Contraction, Theory of Vibrations, Placental Blood, Respiration, Venous Absorption, Craniology, Sympathy, Cerebral Pulsations, Theory of Sleep, &c., comprehending the experiments and reasoning of Galen, Harvey, Haller, Hunter, Monro, Spallanzani, Blumenbach, Philip, Bichat, Gordon, Legallois, Tiedeman, and many others.

To enable the student more easily to comprehend the New Doctrine of Tissues, an extensive Table of their names, division, position, character, and chemical composition, has been composed. Another, comprising the Fluids, is added, on the same plan. He will thus have presented to him, under one view, what hitherto could only be acquired with considerable labour: but he will remember that the translator's accuracy is no farther pledged than for the careful collection of those materials from the best authors. On the contrary, he has ventured to express his doubts of many of them, by a note of interrogation; and, perhaps, might have subjoined it to many more, without offence to strict truth. To these Tables a few others, less useful, are added.

To critics, who value elegance not less than utility, some little apology must be necessary, by way of anticipation, for the slips they may here and there discover in the text. The Translator has long thought that much of the obscurity and *ennui* of physiological discussion arises from that obscure polysyllabic dialect in which it has hitherto been couched: and to avoid this inconvenience, he has studied plainness of language, almost to rusticity.—The original is by no means a physiological rhapsody, whose charms could only be preserved in English by a corresponding profusion of Greek and Latin derivatives, connected by trim phraseology, and smoothly rounded periods: it is a plain, sensible summary of the science, which it has been the author's main wish to express in the simplest language; in whose translation perspicuity must be the highest ornament,—and to which, therefore, the Translator has willingly sacrificed the sickly graces of composition.

THE AUTHOR'S PREFACE.

My principal object, in composing the following work, has been to contribute to the introduction of the Baconian method of induction into Physiological science; at least I have done my best to present the science under the Theoretical form; following, meanwhile, in the exposition of facts, the inductive, or analytical method.

The reader, then, will find, more especially, a number of facts in this book of which I have myself established the certainty, sometimes by observation upon man in health or disease, sometimes by experiments upon living animals. Amongst these facts, the reader will observe many which are entirely new.

I have not, nevertheless, neglected the possible and useful application of the principles of natural philosophy, mechanics, chemistry, &c., to the phenomena of life: perhaps they may appear different from those which have hitherto been advanced; for I have spared no pains to ascertain their accuracy*.

Human Physiology is the only subject which it was my intention to consider: General Physiology, which comprises the history of all living bodies, whether animal or vegetable, is not yet sufficiently advanced to admit of being formed into a complete body of science; and the parts of it which have reached the necessary maturity and exactness, are not of a nature proper to enter into an elementary work. I must finally observe, that my book is solely destined for the benefit of students in medicine. If they find in it all that is positively known and established in Physiology, expressed in clear and simple language, I shall have attained the object which I originally proposed.†

* Our judicious author is not one of the many who seek to rise in the esteem of the medical vulgar, by flattering its prejudices. Of late, many such writers have affected to banish all mechanical conclusion from Physiology; as if every function or action of the body could only be explained by the *laws of the vital principle*: but without showing us what that principle is, or the extent of its laws. The reader who is capable of analyzing his own ideas, will discover, on a little reflection, that we have not the slightest notion of any action or motion, but what is drawn from the motions and actions of the inanimate world; and that though such actions in the living body are doubtless liable to modification from the vital principle, yet, in their study, we no more advance our knowledge by refusing the aid of mechanics, than the sailor or engineer, who for the same reason should refuse to believe that the steam engine working in his service, was equivalent to the *power of ten, twenty, or forty horses*, because forsooth those animals being actuated by the vital principle, often act in a way which we cannot explain by mechanics; we should rather imitate the judgment of these sensible artists, who admit all that they know of both brute and animal matter into their computation, and when that proves insufficient, confess their ignorance. Furious *anti-physical* Physiologists may derive much instruction from the perusal of an elegant passage in Richerand's Physiol. I. 352, (*Ed.* 1820, *Par.*) which we have not leisure to transcribe here.—Tr.

† I gladly embrace this opportunity of returning in a public manner my grateful thanks to Doctor Edwards, who assisted at all my experiments, and whose great information and judicious remarks, have been of the highest advantage to me in arranging the materials of this work.

COMPENDIUM

OF

PHYSIOLOGY.

General Physiology is that natural science which has for its object the knowledge of the phenomena proper to living bodies. It is divided into Vegetable Physiology, which is employed in the consideration of vegetables; into Animal, or Comparative Physiology, which treats of animals; and into Human Physiology, of which the special object is Man. It is of this last that we propose to treat in the following work.

PRELIMINARY CONSIDERATIONS.

Of Bodies, and of their Divisions.

Whatever is capable of acting on our senses we denominate *body*. Of Bodies, and of their Divisions.

Bodies are divided into Ponderable and Imponderable. The first are those which may act upon several of our senses, and of which the existence is sufficiently established; of this kind are solids, fluids, and gases. Ponderable Bodies.

The second are those which, in general, only act on one of our senses, whose existence is by no means demonstrated, and which, perhaps, are only forces, or a modification of other bodies; such are caloric, light, the electric and magnetic fluids. Imponderable Bodies.

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

The general properties of bodies are,—extent, divisibility, impenetrability, mobility. General Properties of Bodies.

A ponderable body, of whatever kind, always presents these four properties combined.

Secondary Properties.

State of Bodies.

Changes of State.

Secondary properties are variously distributed amongst different bodies; as, hardness, porosity, elasticity, fluidity, &c. (1) They constitute, by their combination with the general properties, the condition, or state of bodies. It is by gaining or losing some of these secondary properties that bodies change their state: for instance, water may appear under the form of ice, of a fluid, or of vapour, although it is always the same body. To present itself successively under these three forms, nothing more is necessary than the addition or abstraction of some of its secondary qualities.

Composition of Bodies.

Simple Bodies.

Bodies are simple, or compound. Simple bodies are rarely met with in nature; they are almost always the product of art, and we even name them simple, only because art has not arrived at their decomposition. At present, the bodies regarded as simple are the following:—Oxygen, chlorine, iodine, fluorine, sulphur, hydrogen, boracium, carbon, phosphorus, azote, silicium, zirconium, aluminum, yttrium, glucinum, magnesium, calcium, strontium, barium, sodium, potassium, manganese, zinc, iron, tin, arsenic, molybdenum, chromium, tungsten, columbium, antimony, uranium, cerium, cobalt, titanium, bismuth, copper, tellurium, nickel, lead, mercury, osmium, silver, rhodium, palladium, gold, platinum, iridium. (2)

Compound Bodies.

Compound bodies occur every where; they form the mass of the globe, and that of all the beings which are seen on its surface. Certain bodies have a constant composition; that is to say, a composition that never is changed, at least from accidental circumstances: there are, on the contrary, bodies whose composition is changed at every instant.

This diversity of bodies is extremely important; it divides them naturally into two classes: bodies, whose com-

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(1) The few elementary principles of physics here introduced, are necessary for the general coherence of the work. The distinction of the properties or qualities of bodies into primary and secondary, adds scarcely any thing to our knowledge, and has, therefore, been more employed by metaphysicians than natural philosophers. It is one of the many scientific generalizations, which connect objects only by those relations which are useless.

(2) To the simple bodies here given, must be added the recent discoveries of Selenium, Lithium, Thorinum, Wodanium, Cadmium. So rapid and so successful are the advances of modern chemistry, that possibly some farther additions may be necessary before the present note can go to press.

position is constant, are named brute, or gross, inert, inorganic; but those whose elements continually vary, are called living, organized bodies. (3)

Brute, and organized bodies, differ from each other in respect, 1st, of form; 2d, of composition; 3d, of the laws which regulate their changes of state. The following table presents the differences which are best marked.

TABLE I.

DIFFERENCES BETWEEN INORGANIC AND LIVING BODIES.

Differences of Inorganic and Living Bodies.

1. *Form.*

Inorganic Bodies.	Living Bodies.
Angular Form. Indeterminate Volume.	Rounded Form. Determinate Volume.

2. *Composition.*

Inorganic Bodies.	Living Bodies.
Sometimes simple.	Never simple.
Seldom of more than 3 elements.	At least 4 elements, often 8 or 10.
Constant.	Variable.
Each part capable of existing independent of the others.	Each part more or less depending on the whole.
Capable of being decomposed and recomposed.	Capable of decomposition, but totally incapable of recomposition.

3. *Regulating Laws.*

Inorganic Bodies.	Living Bodies.
Entirely subject to attraction, and chemical affinity.	In part subject to attraction and chemical affinity. In part subject to a power unknown.

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(3) The distinction of matter into organic and inorganic, or organized and brute substances, is one of obvious necessity; yet it is no easy matter to define the nature and limits of each. Is the prussic acid, or the carburetted, or sulphuretted hydrogen, so copiously evolved from what is called organic matter, to be classed with brute or with organized substances? If easy decomposition characterizes the latter, who can refuse this property to the substances just cited? Nay, the presence of nitrogen in the first of them, and their readily affording gaseous products from external agency, must still farther confirm their claim. Yet, if this were admitted, it must be granted that we possess a power of giving origin to organic bodies at our pleasure, since these gases are every day formed by artificial means.

Again, if a certain definite arrangement of internal particles be said to be essential to organization, the same is also necessary to many crystals, and perhaps to every mineral, &c. (See Hibbert's Shetland); and many of them, as stalactites and petrifactions, evidently acquire this from the influence of external agents. Not a few bodies, manifestly organic, become, by compression, petrifaction, and impregnation, manifestly brute, as we see in coal, petrifactions, and perhaps in the vitriolised man, whose case is mentioned in the Philosophical Transactions, No. 384. p. 236. If such is the ambiguity of this distinction, the student must be careful to

Living bodies are divided into two classes, one of which comprehends *Vegetables*, the other *Animals*.

TABLE II.

Differences between Vegetables and Animals.

DIFFERENCES BETWEEN VEGETABLES AND ANIMALS. (4)

Vegetables,	*Animals,*
Are fixed to the ground.	Move on the surface of the ground.
Have carbon for the principal base of their composition.	Have azote for the base of their composition.
Composed of four or five elements.	Often composed of eight or ten elements.
Find and assume in their vicinity their nourishment in a state of preparation.	Must act on their aliments, in order to render them fit for nourishment.

Elements which enter into the composition of the bodies of Animals.

Elements which constitute Animals.

The consideration of those elements which may enter into the composition of the bodies of animals, is not merely useful in a physiological point of view; it furnishes likewise several truths important to the physician in the treatment of diseases. These elements are solid, liquid, gaseous, and inconfinable.

Solid Elements.

Solid Elements.

Phosphorus, sulphur, carbon, iron, manganese, potash, lime, soda, magnesia, silica, and alumina. (5)

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employ it only in those obvious cases wherein there can exist no possible source of error. The tables delivered in the text may often serve to lessen his difficulty.

(4) A less exceptionable distinction than any here given between animals and vegetables, is the general fact, that the former are nourished by *an internal canal*, bearing always a very appreciable proportion to the diameter of the trunk: whilst the latter imbibe their food from the surrounding contingent bodies, by means of *capillary tubes* of inappreciable relation to the trunk or stem. In short, the animal capillary organs of nutrition lie *within* the alimentary canal: from this reservoir, this elaboratory, they draw their supplies; but the capillaries of the vegetable, *open on its surface*, and, without reservoir, without preparation, draw almost indiscriminately from the soluble matters offered to them in their immediate vicinity.—*See Saussure's Recherches Chymiques sur la Vegetation*, p. 264.

(5) Among the *solid elements* of the human body, potassium, calcium, sodium, magnesium, silicon, aluminum, ought to be substituted for the corresponding names in the text, which are not elements, but true oxides. Fluorine must either be added to the same list or to the liquid elements underneath, as we shall soon see it has been detected by Berzelius, in the osseous tissues.

Liquid Elements.

Liquid Elements.

Muriatic acid; water, which in this case may be considered as an element, enters into the organization, and constitutes three-fourths of the bodies of animals.

Gaseous Elements.

Gaseous Elements.

Oxygen, hydrogen, azote.

Inconfinable Elements.

Inconfinable Elements.

Caloric, light, electric and magnetic fluids.

These diverse elements, united with each other, three and three, four and four, &c. according to laws still unexplained, form what we name the proximate principles of animals.

Proximate Materials, or Principles of Animals.

Proximate Materials or Principles of Animals.

The proximate principles of animals are divided into azotised and non-azotised. (6)

Azotised Principles.

The azotised principles are: albumen, fibrin, gelatin, mucous, cheese-curd principle, urea, uric acid, osmazome, colouring matter of the blood.

Non-azotised Principles.

The non-azotised principles are: the acetic, benzoic, lactic, formic, oxalic, rosacic, acids; sugar of milk, sugar of diabetic urine, picromel, yellow colouring matter of bile, and of other liquids or solids which become yellow accidentally, the blistering principle of cantharides,* spermaceti, biliary calculus, the odoriferous principles of ambergris, musk, castor, civet, &c. which are scarcely known, except for their faculty of acting on the organ of smell.

Animal fats are not immediate, simple, proximate principles. M. Chevreuil has proved that human fat, that of the pig, of the sheep, &c. are principally formed by two fatty bodies, (7) which present very different characters that may be easily separated.

* Now cantharidin.—T.

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(6) The proximate principles of animals, here delivered by our author, will be all found most accurately described in Mr. Thenard's Chemistry, a work not second even to Dr. Thomson's, in the variety and exactness of its information, and naturally superior to it in what relates to the discoveries of the French school. It supplies many of Dr. T.'s omissions.

(7) These are now denominated *stearin* and *elain*.

Neither is the butter of the cow a simple body; it contains acetic acid, a yellow-colouring principle, an odorous principle, which is very manifest in fermented cheese.

We must not reckon amongst these substances, adipocire, a matter which is seen in bodies long buried in the earth: it is composed of margarine, of a fluid acid fat, of an orange-colouring principle, and of a peculiar odorous substance. Nor must this substance be confounded with spermaceti, and the biliary calculus, which are themselves very different from each other. M. Chevreuil has proved that it does not contain a single principle analogous to them.

Organic Elements.

Organic Elements.

These materials combine amongst themselves, and from their combination arise the organic elements, which are solid or liquid. The laws or forces that govern these combinations are entirely unknown. (8)

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(8) Organic elements *may* be retained together by the same attraction of aggregation which unites the particles of inorganic or brute matter. For, though we cannot prove that this is the case, nor explain the mode of operation even in brute matter, there are many arguments that forbid our assuming a new, and, if possible, more obscure principle of explanation. The organic elements readily exert the common aggregating attraction towards other substances: thus, albumen unites with chloride of mercury, fibrin with acetic acids, stearin, zimome, and resins, with alcohol. Oil and resin unite together—so do albumen and oil: all oily matters are affected by capillary attraction. Organic bodies, on uniting, manifest a change of electricity and temperature: in short, there is no modification of the aggregative attraction, even supposing it, with Berthollet (Chym. Stat.) the cause of chemical attraction, which the organic elements do not display in common with brute matter. Many phenomena, indeed, appear, which we cannot explain; but, be it remembered, that, connected with the actions of the organic elements in a living body, there is always a powerful impulse present, of whose powers and operations we know scarcely any thing, except their great energy. Who can explain why sulphur attracts oxygen, or what power is exerted by water or potass, in promoting the combination? Yet, these are, of all physical agents, the four bodies best understood by philosophers; and it surely would not have facilitated the solution of the problem, had we supposed, as in the analogous case of life, the properties and influence of the predisposing agent to be totally unknown. Till the influence of life on the actions of organic elements shall be understood, it will be well to hazard no conjectures upon the principle by which they are effected.

It is not quite so easy, however, at least for a mind of geometrical training, to divest our thoughts of the mechanical idea of the textures being constructed from simple fibres. Nearly all the substances in nature, brute or organized, may, by some means or other, be reduced to fibres,—the mineral by crystallization, the membrane by drying, the bone by maceration, &c.; even the fleecy honours of the sky may frequently be observed

Organic Solids.

Organic Solids.

The solids have sometimes the form of canals, sometimes that of large or small plates, at other times they assume that of membranes. In man the total weight of solids is generally eight or nine times less than that of liquids.—This proportion is nevertheless variable according to many circumstances.

Elementary Fibre of the Ancients.

The ancients believed that all the organic solids might be reduced by ultimate analysis to simple fibres, which they supposed were formed of earth, oil, and iron. Haller, who admitted this idea of the ancients, owns that this fibre is visible only to the eye of the mind.* This is just the same as if he had said that it does not exist at all, of which nobody at present doubts.

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

Professor Chaussier has lately proposed to admit four sorts of fibres, which he calls *laminary*, *nerval*, *muscular*, and *albuginous*.

Of the Systems.

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. He founded several orders of diseases upon this division, but particularly the phlegmasiae. Bichât laid hold of this fine conception, and applied it to all the solid parts of the bodies of animals: his work on this subject constitutes his best title to fame.† The classification of Bichât has been perfected by M. Dupuytren; several faults that it presented have also been noticed by M. Richerand. (9)

* Invisibilis est ea fibra sola; mentis acie distinguimus.

† See the Treatise of General Anatomy.

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to assume this form; and a German philosopher maintains, that the whole human body is nothing but a crystal. The mind naturally supposes these fibres to be further indefinitely divisible; and as the geometer always conceives magnitude to be divisible in this way, it is not without some effort that we learn to consider the tissues as simple, and, perhaps it may be added, that the conviction is rarely permanent. All the great physiologists relapse into ordinary language in those parts of their writings, where no theory was present which might put them on their guard against its use.

(9) It is lamentable to observe the obstinate tenacity with which the philosophers of Europe continue to vitiate the truth of history, in order to arrogate to themselves, or their countrymen, the glory of scientific dis-

We here give the classification of the tissues, rectified according to the ideas of MM. Dupuytren and Richerand.

1. Cellular		System.
2. Vascular	Arterial. Venous. Lymphatic.	
3. Nervous	Cerebral. Ganglaic.	
4. Osseous		
5. Fibrous	Fibrous. Fibro-Cartilaginous. Dermoid.	
6. Muscular	Voluntary. Involuntary.	
7. Erectile		
8. Mucous		
9. Serous		
10. Horny or Epedermic	Hairy. Epidermoid.	
11. Parenchymatous	Glandular.	

coveries. Perhaps the true reason why the French are oftener than any other nation of Europe accused of this failing, may be found in their ignorance of other languages, and the multiplicity of their own literature, which does not leave sufficient time, even to the most diligent, for a due examination of foreign works. Indeed, among the *imi subsellii* authors of our own country, the same abuse of history is nearly as flagrant as among our more vain and ambitious neighbours. Without implicating our author, the fact against the French is strong in the present instance of the division of the system into tissues,—a beautiful generalization, of which the clear explanation is certainly due to Bichât, though the invention attributed to him in the text neither belongs to Bichât nor Pinel,—nor, indeed, to John Hunter or Carmichael Smyth. Scattered hints of comparison between the different structures are to be met with in earlier writers; but it was Andrew Bonn, who, in a Thesis of 1763, still to be seen in Sandifort's Collection, first pointed out their continuations, limits, characters, and differences. The work is entitled *De Continuationibus Membranarum*, and still merits an attentive reading: it contains many of those fine observations which have generally been attributed to Bichât, such as the opening of the Fallopian tubes into the cavity of the peritoneum, and the continuation of the tunica arachnoides along the veins of the sinuses, into the dura mater. On this last head, the author is quoted by Haller (*Auctar. ad librum* x. p. 149. *Element. Physiolog.*) with praise; and, considering the great celebrity of the respective works of Haller and Sandifort, it cannot be supposed that either Pinel or Bichât were unacquainted with the labours of Bonn, who was, in their time, eminent as a pathologist. In the London Medical Communications, (vol. ii. 1788) is a paper on Inflammation, by Carmichael Smyth, in which he has anticipated many of Bichât's pathological remarks on the different tissues, (Monro's Outlines of Anatomy, vol. i. p. 4.), but it does not appear that the Doctor had known any thing of Bonn. John Hunter is also entitled to a priority of the same kind, but his hints are unconnected. Comparing the date of these publications with that of Pinel's

These systems, associated with each other and with the fluids, compose the *organs*, or instruments of life. When Organs and Apparatus.

Nosographie, 1788, and Bichât's *Traité sur les Membranes*, in 1800, the candid reader will easily perceive that it is not the praise of prior, but of superior writing, on this most important subject, which is due to the latter. "The new system," says Monro *tertius*, "has prepared the way to a more minute, accurate, and philosophic examination of the structure and properties of our different organs; and has tended very much to the advancement of physiological and pathological science; both of which have assumed, under its influence, a new aspect." Bichât's original work entitled *On the Membranes*, was afterwards re-cast into his larger book of General Anatomy; and in the latter, the arrangement of the textures, or tissues, as they are termed by anatomists, is as follows:—

BICHAT'S CLASSIFICATION.

1. Cellular
2. Nervous *animal*
3. Nervous *organic*
4. Arterial
5. Venous
6. Exhalant
7. Absorbent, with their glands
8. Osseous
9. Medullary
10. Cartilaginous
11. Fibrous
12. Fibro-cartilaginous
13. Muscular *animal*
14. Muscular *organic*
15. Mucous
16. Serous
17. Synovial
18. Glandular
19. Dermoid
20. Epidermoid
21. Pilous

} Systems.

The following classification of Dumas has the merit of great simplicity:—

1. Nervous, or sensitive.
2. Muscular, or motive.
3. Vascular, or calorific.
4. Visceral, or reparative.
5. Lymphatic, or collective.
6. Sexual, or reproductive.
7. Osseous, or fundamental.

It comprehends, however, only a few of the textures, and some of them are repeated; whilst the membranes, of the whole the most important, are strangely omitted.

The improvement on Bichât's arrangement given in the text is liable to several objections from which the original is free. In both, the fibrous system cannot be defined. Why exclude from it the muscles, nerves, and hairs, which are all divisible into fibres? why include in it the cartilages of joints in which no fair anatomy can easily detect a fibre? This class must many organs tend by their action towards a common end, we name them, collectively considered, an *apparatus.* The number of apparatus, and their disposition, constitute the differences of animals.

Properties of Tissue.

Properties of Tissue.

The textures which compose the different organs, have chemical and physical properties which it is important to study on the dead subject and in the living animal. We find in these almost all the physical qualities which are observed in inorganic bodies: different degrees of consistence from extreme hardness to fluidity, elasticity, transparency, refractiveness, &c.; but we are particularly attracted by certain qualities, which have been named the *properties of tissue.* These are the extensibility and contractility of tissue; the contractility *par racornissement,* (i. e. the contractility from crispation.) (10) Independent-

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be considered to be entirely empirical. There is still much doubt to which of the classes the erectile organs ought to be referred; but this will hardly warrant their being elevated to the rank of an insubordinate tissue. Lastly, it is perhaps too fine a generalization to include the lymphatics with the other vessels; the vasa deferentia, the ureters, urethra, and the intestines themselves, might all, on such slender analogy, have been comprehended under the same head; they are all *vascular.* But the pathology, anatomy, and function of the lymphatics differ so widely from those of the blood-vessels, that an arrangement which, like the present, compels them to approximate, is more likely to mislead than instruct. The tendency of Bichât's classification was to refine on subdivision, to magnify insignificant differences: that of the present professors would sink the pleasing variety of nature in vague conjectural abstractions, which ignorant fancy so often substitutes for the true relations of things. We shall, in another place, present the reader with the distinguishing characters of the individual textures; at present we would merely introduce to his notice the staple material on which the fame of Bichât must always rest, and mark out his share in the invention and improvement of the doctrine of tissues. Had our limits permitted, we designed to point out the errors, *confugia ignorantiae,* and other mischiefs to which the new divisions have given rise in pathology; but we feel ourselves confined to the delivery of the following general maxim: *that no reasoning from similarity of tissue is ever correct, except where that similarity extends to vital and functionary properties.* Thus the mucous membranes of the eye, nose, and lungs, are homogeneous, but carbonic acid gas or cold will not produce the same effect on any two of them, and still less upon the lining of the tympanum of the ear, or of the rectum; they are similar, not the same.

(10) The contractility *par racornissement* seems after all but a simple matter. Bodies containing albumen or much fluid are most subject to it, and, it may be, that the evaporation of the water, and the induration of the albumen, give rise to the phenomena by bringing the particles nearer to each other. Card paper and clay contract pretty much in the same way,

ly of these physical qualities, the tissues have been studied in respect of their composition, and it has been found that some are principally composed of gelatine, others of albumen, others of phosphate of lime, others of fibrine, and so on.

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

One particular science is consecrated to the explanation of the tissues under the threefold relation of their physical, chemical, and vital properties: it is named general anatomy, the study of which is of the highest importance to physiology.*

Of the Fluids or Humours.

The fluids of animal bodies, and particularly those of the human body, are something very considerable in proportion to the solids; the ratio in the adult being as nine to one. Professor Chaussier put a dead body of 120 pounds into an oven, and found it, after many days' successive desiccation, reduced to 12 pounds. Bodies found, after being buried for a long time in the burning sands of the Arabian deserts, present an extraordinary diminution of weight. (11)

* See the *Anatomie Generale* of Bichât.

and from a similar cause. (*See Bichât's Anat. generale, p.* 31, *& Suiv.*) Without being well understood, it has been dragged into the vexatious controversy concerning the contractile properties of arteries.

(11) Though true in the detail, these and similar observations must not be considered as expressing the true relations of the solid to the fluid in the body of man. A great proportion of the body, or almost the whole of it, may pass off slowly in one or other of the gaseous forms it usually assumes in the putrefactive state; its carbon, nay its hydrogen too, may unite with the oxygen of the atmosphere and produce carbonic acid and water. Moreover, in those *dry* situations in which only the experiment can be made, the surrounding bodies, by their affinity for water, probably dispose the oxygen and hydrogen of the animal solid itself, to unite, and pass off in the form of aqueous vapour. That hydrogen and carbon pass off in some way of this kind has long been observed from the effects of the atmosphere on wood, coals, charcoal, exposed to it; as also on oil spread upon organic substances. On the other hand, as the body becomes drier, its avidity for water increases, till at length this overcomes all external action. A mummy, therefore, to speak chemically, is a mere hydrate of humanity; and without a correct appreciation of the quantity of decomposition which takes place during drying, and of the ratio of *hydration* in the different organic elements which constitute man, we shall never be able

The animal fluids are sometimes contained in vessels, wherein they move with more or less rapidity; sometimes in little areolae or spaces, where they seem to be kept in reserve; and at other times they are placed in the great cavities where they make only a temporary stay of longer or shorter duration.

Synoptical Table of Fluids.

The fluids of the human body, which is the principal object of our study, are—(12)

1st, The blood.

2d, The lymph.

3d, The perspiratory or perspirable fluids, which comprise the liquids of cutaneous transpiration: the transpiration or exhalation of mucous membranes, as also of the synovial, serous and cellular; of the adipose cells, the medullary membranes, the thyroid and thymus glands, &c.

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to render a satisfactory reply to this interesting question. To the data afforded by our author it may be added, that the bodies of the Guanches, a primitive race, whose nobles are still found in mummy in the cavities of Teneriffe, often do not weigh more than 7 pounds. *M. Brun, Geogr.* V. 146.

(12) Besides the classifications of the fluids given in this and the succeeding page, there are several others which ought to be known to the student, as they mingle themselves with the ordinary language of medicine. Thus, in relation to their origin, they are divided into Secretions and Excretions: that fluid being considered as a *secretion* which, after its formation becomes subservient to some use within the body: and all others which are merely thrown off from the system, and have no purpose to serve within it, are denominated *excretions*. Dr. Gregory, in his view of Theoretic Medicine, No. 688, 689, divides them, after Fourcroy, into, 1. *watery*; 2. *mucous*; 3. *glutinous or albuminous*; 4. *oily fluids*. This division is beyond all question the most useful, though far from absolute accuracy, as the proximate principles from which the names are derived, are frequently found combined in the same fluid. They must be understood, therefore, as relating to the predominating proximate principle. The late excellent Dr. Gordon, of this place, rather preferred a division of fluids according to the structure of the secreting organs. Of these he constituted the three following classes:

"1. Organs secreting by the tubes formed from lesser tubes.

"2. Organs secreting by pores whose communications within these organs are unknown.

"3. Organs in which the secreted substances cannot be supposed to escape either through tubes or pores." (*Outlines of Physiology*, p. 67.) It must not be supposed that such divisions of the solids and fluids are without their use; they certainly afford little insight into the operations of nature,—but they are the arranged vocabularies of physiological language, and afford an easy mode of acquiring its terms, which are a sort of short-hand abbreviation of many very complex ideas, not to be understood without clear definition, and a frequent juxta-position with other terms to which they are naturally related.

4th, The follicular fluids; the sebaceous secretion of the skin, the cerumen, the ropy matter of the eye-lids, the mucous from the glands and follicles of that name from the tonsils, the cardiac glands, the prostate, the vicinity of the anus, and some other parts.

5th, The glandular fluids; the tears, the saliva, the pancreatic fluid, the bile, the urine, the secretion from Cowper's glands, the semen, the milk, the liquid contained in the supra-renal capsules, that of the testicles, and of the mammae of new-born infants.

6th, The chyme and the chyle.

The properties of fluids, both chemical and physical, are exceedingly various. Many have some analogy to each other under these two relations; but none exhibit a perfect resemblance. The writers of all ages have attached a considerable degree of importance to their methodical arrangement; and according to the doctrine then flourishing in the schools, they have created different systems of classification. Thus, the ancients, who attributed much importance to the four elements, said that there were four principal humours, the blood, the lymph, or *pituita*, the yellow bile, the black bile, or *atra bilis;* and these four humours corresponded to the four elements, to the four seasons of the year, to the four divisions of the day, and to the four temperaments.

Classification of the Fluids.

Afterwards, at different periods, other divisions have been substituted, to this classification of the ancients. Thus, some have made three classes of liquids:—1st, the chyme and chyle; 2d, the blood; 3d, the humours emanating from the blood. Some authors have been content with forming two classes:—1st, *primary*, alimentary or useless fluids: 2nd, *secondary* or useful. Consequently, they distinguished them into—1st, *recrementitious* humours, or humours destined from their formation to the nourishment of the body; 2d, *excrementitious*, or fluids destined to be thrown off from the system; 3d, humours, which at times participate in the characters of the two former classes, and are therefore named *excremento-recrementitious.* In later times, chemists have endeavoured to class the humours according to their intimate or component nature, and thus they have established albuminous, fibrinous, saponaceous, watery, &c. fluids.

The classification admitted by Professor Chaussier seems much preferable. It has no relation to the nature of the fluids, or to the offices which they fulfil, but it is founded upon the mode of their *formation*, the only invariable character which they offer. It is the arrangement which we have followed in the enumeration of fluids, just delivered in the Synoptical table of fluids. (13)

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(13) In a former note we have said, that the parts of the body in the *state of life*, exhibit very different properties and relations from those which are seen, when this state no longer exists. We did not, however, assert that this state depended on any particular *principle, law, body,* or *being* whatever: in short, it is not known on what it depends, and the absurdity of the theories briefly alluded to below by M. Magendie, lies wholly in this, that they all assume some single agent as the cause or essence of this state, and even presume to name it, although obviously without any possible means of discovering either its connection with the state of life, or even its individual existence. It is unworthy of the accurate philosophy of the present age, to continue the use of a term which absolutely means nothing but a confession of our ignorance of the cause of the state of life; for, when a theorist assures us that the adhesion or renovation of a wounded part, is the effect of the vital principle, he does not mean us to infer that he knows any thing of this vital principle, or the way in which it brings about adhesion; he merely intends to say that adhesion is a phenomenon that never takes place, (and which, he therefore *infers*, never can take place,) except in a state of life. Since such is his meaning, why not employ the language which expresses his ideas in the least ambiguous manner? It is surely the rule to do so in every other case. The primary idea of life in our language signifies *motion*, in the learned languages *force* or *power*; and if we analyse the idea as it arises in our minds, we shall find that *an inherent, or independent power of motion, accompanied by frequent actual, appreciable, motion*, constitutes the whole of our notion of life, before it is adulterated by the study of the natural sciences, and the writings of philosophers. In the progress of the mind through this discipline, all the qualities and phenomena seen or supposed to be peculiar to the body in the state of life are successively tagged to the original idea, till at last it comes, as we have just said, to be nothing but a short expression for that state, or for the awkward conjectures of philosophers respecting its cause. That this cause is single, we have no reason whatever to presume; on the contrary, its efforts are now salutary, now pernicious; vary greatly at different periods, are obviously affected by education, habit, and external circumstances of particular organs; and on the whole, exhibit such opposite and contradictory tendencies in many cases, that we may with much better reason infer a plurality of agents, than one single solitary cause of the multifarious phenomena of life. The reader who is in quest of ingenious speculation on this subject, will find much to his purpose in Dr. Fleming's Philosophy of Zoology, vol. 1. p. 120—130, but especially in Dr. Barclay's Book on Life and Organization; the author of which has long attended to the subject, but seems unfortunately to have thought the opinions of others of more value to the public, than his own, a piece of modesty with which his readers could well have dispensed, as on the arena of conjecture all men stand equal who are equally well informed. He has also shown rather more tenderness for the visions of some learned dreamers than was to be expected from "That sheer wit which never spared a quack;"—but he richly compensates for both omissions by the vast fund

Causes of the Phenomena proper to Living Bodies.

From the most remote antiquity, philosophers were persuaded that a great part of the phenomena peculiar to living bodies, did not follow the same course, nor obey the same laws, as the phenomena proper to brute matter.

Causes of the Phenomena proper to Living Bodies.

To these phenomena of living bodies, a particular cause has been assigned, which has received different denominations. Hippocrates bestows on it the appellation of PHYSIS, or nature; Aristotle calls it the *moving* or *generating principle;* Kaw Boerhaave the *impetum faciens;* Van Helmont, *archaeus;* Stahl, the *soul;* others, the *vis insita, vis vitae,* vital principle, &c.; M. Chaussier, in his learned lectures, and *in his synoptical table of the characters of the vital force,* adopts the name of *vital force.*

There can be no deception in the interpretation of the term *vital force;* it signifies, and indeed can signify nothing else than the *unknown cause* of the phenomena of life.

Moreover, physiologists maintain, that attraction presides over the changes of state, which occur in inert bodies, just as the vital force regulates the modifications of those which are organized; but they hereby 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 force lie totally concealed. With regard to it, indeed, physiology is exactly at that point, where the physical sciences were before the time of Newton;—it waits till a genius of the first order arrive, to discover the laws of the vital force, as Newton made known to us the laws of attraction. The glory of that great mathematician did not consist, as some think, in having discovered attraction—that cause of action was known before him—

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of information he has collected into one view, carefully classified, and illustrated by his own judicious remarks. Dr. W. Philip's work on the Vital Functions, may also be consulted with advantage, though the author cannot be defended, for the very lax sense in which he employs most of the terms concerned in the designation of this most obscure, though important part of our existence. The student will do well, in all such dubious expressions, to substitute for *vital principle,* the words *vital state,* or *vital action;* he will thereby reduce a theory to fact, and avoid all chance of being misled by his author. The reduction of a complicated train of phenomena to a single cause, may indeed gratify our vanity, and flatter us with a seeming advance of our knowledge; but such a reduction, in order to be useful, ought to be capable of verification, which is not the case in the present instance.

but rather in having told us *that attraction acts in the direct ratio of the mass, and inversely as the square of the distance.*

Vital Properties.

In the explication of vital phenomena, we are by no means compelled to admit the operation of the vital force, or to assign to it extensive influence. It has been supposed that this force manifests itself by vital properties, upon which some authors have founded not only the science of Physiology, but even Pathology and Therapeutics.

These vital properties generally admitted, have received different names: thus they are called,

1. Organic,—vegetative,—nutritive,—molecular sensibility.

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

3. Cerebral,—animal,—perceptive sensibility; the sensibility of relation, &c.

4. Sensible organic sensibility, irritability, vermicular motion.

5. Voluntary, animal contractility: the contractility of relation.

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

It is the former alone which deserve the name of vital properties; but it is essential to remark that organic sensibility, and insensible organic contractility, by no means come under that signification. They are evidently supposititious modes of conception, and of explaining the phenomena of life. In reality, they do not at all exist; and nevertheless, it seems that no one, at present, disputes their existence. We speak of the alterations which they undergo, of the necessity of reducing them to their ordinary state: and some have even gone the length to class remedies after their mode of operation upon these properties, and many physicians treat their patients according to this doctrine. But this chief fundamental of physiology and medicine is evidently vicious.

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

The *cerebral*, or *animal sensibility*, as Bichât names it, and also the voluntary contractility, have only been enumerated amongst the vital properties by an abuse of words; it being evident that they are *functions*, or the results of the action of many organs, which in acting, have one common object to be attained.

We say nothing of the *force of vital resistance*, of *fixed situation*, of *vital affinity*, of *caloricity*; because those different properties though proposed by authors of great merit, have not obtained general assent, nor can we see any necessity for admitting them.

Our opinion, then, respecting the vital properties, reduces itself to this; we reject *insensible organic contractility*, and *organic sensibility*, as useless and dangerous hypotheses: and consider *organic sensible contractility*, merely as the action of an organ, and both *voluntary contractility*, and *voluntary sensibility*, as functions.

Phenomena of the life of Fluids.

The doctrine of vital properties has not been ever applied to the fluids, and yet physiologists agree in considering them possessed of life. (14) But in fact they have acted more circumspectly in regard to the fluids than the solids: for they have concluded that they are endowed with life, solely from the phenomena which they present. Thus, the fluidity, which they preserve, as long as they constitute a part of the animal; the manner in which some organize themselves, as soon as they are separated from the vessels; the power of producing heat, &c., are leading phenomena, which according to modern physiologists, evince that the fluids are alive. Nevertheless, it is proper to add, that all the animal fluids do not offer these characters. The blood, the chyle, the lymph, and some other fluids destined to nutrition, are the only humours which present them. The excrementitious fluids, such as the bile, urine, cutaneous exhalation, &c., exhibit nothing analogous to

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(14) See Barclay on Life and Organization, art. *blood, p.* 478. The life of fluids seems revolting to our common sense, because we are unaccustomed to attribute to them any inherent power of motion, or indeed of any movement, independent of external impulse. It is not easy to conceive of their becoming capable of either, and as the structure of fluids is too simple to admit of any internal mechanism which might supply the place of these essential characters of life, it would be less paradoxical in authors to affirm, that the animal fluids exhibit some of the properties of the living solids, supposed to be peculiar, than to proclaim, that they are actually possessed of life.

these; so that whatever is said of the life of the fluids, applies not to the latter.

Before commencing the study of the phenomena of human life, the proper object of this work, it will be necessary to make one general observation.

Whatever be the number or diversity of the appearances presented by living man, it is easy to see that they can all be reduced, in their ultimate simplification, to two principles, which are *nutrition*, and *vital action*. A few words upon each of these become indispensable in order to comprehend what follows.

General Idea of Nutrition.

The life of man, and that of other organized bodies, is founded upon this, that they habitually assimilate to themselves a certain quantity of matter, which we name aliment. The privation of that matter, during even a very limited period, brings with it necessarily the cessation of life. On the other side, daily observation teaches, that the organs of man, as well as those of all living beings, lose, at each instant, a certain quantity of that matter which composes them: nay, it is on the necessity of repairing these habitual losses that the want of aliment is founded. From these two data, and some others which we shall make known afterwards, we justly conclude, that living bodies are by no means composed always of the same matter at every period of their existence; physiologists have even gone so far as to say, that bodies undergo an entire renovation.

The ancients maintained, that the renovation is effected in the space of seven years. Without admitting this conjectural idea, we shall say that it is extremely probable that all parts of the body of man experience an intestine movement, which has the double effect of expelling the molecules that can or ought no longer to compose the organs, and of replacing them by new molecules. This internal, intimate motion, constitutes nutrition. It falls not under the senses; but with effects so palpable, it would be giving into an absurd scepticism to attempt to call it in question.

This motion is susceptible of no explanation: it cannot, in the present state of physiology, be referred to the molecular movements which regulate chemical affinity. To affirm that it depends upon *organic sensibility*, and *organic insensible contractility*, or simply upon *the vital force*, is to express the fact in different terms, not to give an explanation. Whatever it be, it is by virtue of the nutritive motion, or of nutrition, that the organs of the human body preserve or change their physical properties. As our different organs present different physical properties, the nutritive motion should be different in every one of them.

Independently of the physical properties which the different parts of the body present, there is a great number that exhibit, either in continuation, or at periods more or less connected, a phenomenon that is called *vital action*—for instance, the liver, by virtue of a power which is peculiar to it, forms continually a liquid which is called bile: the same thing takes place in the kidneys with regard to the urine. The voluntary muscles, in certain states, become hard, change their form, and contract. This is another example of *vital action*.—These *vital actions* perform a very considerable part, both in the life of man and of animals; and upon these the attention of the physiologist ought to be particularly fixed.

Vital action depends evidently upon nutrition, and reciprocally, nutrition is influenced by vital action.—Thus an organ that ceases to nourish, loses at the same time its faculty of acting; consequently, the organs whose action is oftenest repeated possess a more active nutrition; and, on the contrary, those that act least, possess a much slower nutritive motion.

The mechanism of vital action is unknown. There passes into the organ that acts an insensible molecular motion, which is as little susceptible of description as the nutritive motion. Every vital action, however simple, is the same in this respect.

All the phenomena of life, then, may be comprehended under nutrition and vital action; but the molecular motions which constitute these two phenomena are not subject to our senses, and it is not upon them that our attention should be fixed; we ought to study only their results, that is, the physical properties of the organs, the sensible effects of vital actions, and endeavour to discover how they both concur in the general effects of life. This is, in fact, the object of physiology.

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

Of the Functions and their Classifications.

The classification of functions by authors has been very various. Without stopping to enumerate the different classifications adopted at different periods of the science, an inquiry, indeed, by no means adapted to this work, we will intimate that the functions may be distinguished into those which are intended to connect the individual with surrounding objects, those whose object is nutrition, and those that have for their object the reproduction of the species. (15)

We shall call the first, *Functions of Relation;* the second, *Nutritive Functions;* and the third, *Generative Functions.**

The plan which it is necessary to follow for the study of a particular function, is by no means a matter of indifference.

We think it necessary to adopt the following:—

1. General idea of the function.
2. Circumstances which put the action of the organs into play, and which we call *excitants* of the functions.
3. Summary anatomical description of the organs that concur in the function, or of the apparatus.
4. Study of every action of the organ in particular.
5. General recapitulation, showing the utility of the function.
6. Relations of the function with those already examined.
7. Modifications which the function presents, according to age, sex, temperament, climate, seasons, habit.

Of the Functions of Relation.

Functions of Relation.

The functions of relation are composed of *sensations,* of *intelligence,* of the *voice,* and of *motion.*

* For the development of the different systems, see the Physiology of Richerand, and Chaussier's Table of Functions. I give the details in my Lectures.

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(15) Drs. Cullen and Gregory, in their physiological works, divide the functions into *animal, vital,* and *natural.* The animal functions distinguish the animal from vegetable or brute matter; they consist in locomotion and the muscular actions; the vital functions are those of the brain, heart, and lungs; and all the rest are called natural functions, such as the *nutritive* and *reproductive* processes, &c. There is a natural foundation for this division, but the denominations of the classes seem puerile, and not sufficiently distinct from each other. A physiologist might feel himself puzzled for an answer, if he were asked why he denominated digestion a natural, and walking an animal action? the truth is, that they are both natural, and both animal actions. Names, however, are of little consequence; and the reader who has toiled over the three spacious charts of the functions, not omitting the chart of *prolegomena,* delivered by Bichât, (Anat. Gener. p. 56,) will have learned to appreciate the superiority of this neat and simple division over all others.

Of Sensation.

The sensations are functions destined to receive the impressions of exterior objects, and to transmit them to the understanding. Of the Sensations.

The number of these functions is five :—*Vision, hearing, smell, taste, touch.*

OF VISION.

Vision is a function which enables us to perceive the magnitude, figure, colour, distance, &c. of bodies. The organs which compose the apparatus of vision enter into action under the influence of a particular excitant, or stimulus, called *light.* Of Vision.

We perceive bodies, we take cognizance of many of their properties, though they are often at a great distance;—there must then be between them and our eye some intermediate agent; this intermediate substance we denominate *light.* Light is an excessively subtile fluid, which emanates from those bodies called *luminous,* as the sun, the fixed stars, bodies in a state of ignition, phosphorescence, &c. Light is composed of atoms which move with a prodigious rapidity, since they pass through about eighty thousand leagues of space in a second. Light.

A series of atoms, or particles, which succeed each other in a right line without interruption, are denominated a *ray of light.* The atoms which compose every ray of light are separated by intervals, that are considerable in proportion to their mass; which circumstance permits a considerable number of rays to cross each other in the same point, without their particles coming in contact. Of the Rays of Light.

The light that proceeds from luminous bodies forms diverging cones, which would prolong themselves indefinitely, did they meet with no obstacles. Philosophers have from thence concluded, that the intensity of light in any place, is always in an inverse ratio to the square of the distance of the luminous bodies from which it proceeds. The cones that are formed by the light in passing from luminous bodies, are, in general, called pencils of light, or pencils of rays, and the bodies through which the light moves are designated by the name of *media.* Intensity of Light.

When light happens to come in contact with certain bodies that are called opaque, it is repulsed, and its direction is modified according to the disposition of those bodies.— Reflection of Light.

The change that light suffers in its course is, in this case, called *reflection.* The study of reflection constitutes that part of physics, which is named *catoptrics.*

Certain bodies allow the light to pass through them; for instance glass: they are said to be *transparent.* In passing through these bodies, light suffers a certain change, which is called *refraction.* As the mechanism of vision rests entirely upon the principles of refraction, the examination of these becomes, therefore, a matter of importance.

Laws of Refraction. The point where a ray of light enters into a medium is called the point of immersion; and that where it goes out is called the point of emergence.

If the ray comes in contact with a medium in a line perpendicular to its surface, the ray then continues its direction without any change; but if its direction is oblique to the surface of the medium, the ray is then turned out of its course, and appears broken at the point of immersion.

The *angle of incidence* is that which the incident ray makes with a perpendicular line drawn over the point of immersion upon the surface of the medium, and the *angle of refraction* is that which the broken ray makes with the perpendicular.

If the ray of light pass from a rare medium into one more dense, it inclines towards the perpendicular at the point of contact; but it declines from it if it pass from a dense medium into one that is rarer. The same phenomenon takes place, but in a contrary direction, when the ray enters into the first medium; this takes place in such a manner, that if the two surfaces of the medium traversed by the ray are parallel to each other, the ray in passing into the surrounding medium, will take a direction parallel to that of the incident ray.

Bodies refract the light in proportion to their density and combustibility.* Thus, of two bodies, of equal density, one of which being composed of more combustible elements than the other, the refractive power of the first will be greater than that of the second.

All transparent bodies refract at the same time that they reflect the light. On account of this property these bodies are capable of being used as a sort of mirror.

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

When their density is very inconsiderable, such as that of the air, they are not visible unless their mass be considerable.

The form of a refractive body has no influence upon its refractive power; but it modifies the disposition of the refracted rays in respect to each other. In fact, the perpendiculars to the surfaces of the body, approaching or receding according to the form of the body, the refracting rays should at the same time approach or recede.

When, by the effort of a refractive body, the rays tend towards each other, the point where they unite is called *the focus of the refractive body*. Bodies of a lenticular* form are those which present principally this phenomenon.

A refractive body, with parallel surfaces, does not change the direction of the rays, but it inclines them towards its axis by a sort of *transportation*. A refractive body of two convex sides does not possess a greater refractive power than a body convex on one side, and plane on the other; but the point behind it in which the rays are united is much nearer.

Composition of Light.

The study of refraction leads us to the observation of a very important circumstance; which is, that *a ray of light* is itself composed of an infinite number of rays, differently coloured, and differently refrangible; that is to say, to every coloured ray corresponds, in the same bodies and for the same incidence, a refraction which varies according to the colour of the rays. If a pencil of rays is made to traverse a prism of glass, or any other refractive body whose surfaces are parallel, the pencil becomes larger, and after it quits the body, if it is received upon a plane, such as a leaf of paper, it occupies a considerable extent; and in place of producing a white image, it produces an oblong image of an infinity of tints which succeed each other by insensible gradations, and amongst which there can be distinguished the seven following colours:—Red, orange, yellow, green, blue, indigo, violet. Each of these colours is indecomposible; the whole form the *solar spectrum*. This light is not homogeneous, since it is composed of rays of very different colours. Upon this fact is founded the explanation of the colours of bodies. A white body is a body which reflects the light without decomposing it; a black body is a body which does not reflect the light,

* Lenticular bodies are those terminated by two spherical segments.

Colouring of Bodies.

but which absorbs it completely. Coloured bodies decompose the light in reflecting it; they absorb a part, and reflect the rest. Thus a body will appear green when the union of the colours that it reflects appears of this colour. Bodies which are transparent appear also coloured by the light that they refract, and it often happens that when seen by refraction they appear of a colour different from what they appear when seen by reflection. If, however, we wish to know why one body reflects a certain colour whilst another body absorbs it, philosophers reply, that this phenomenon depends upon the particular position of the atoms of these bodies.*

The discovery of the action of refractive bodies upon light has not been an object of simple curiosity; it has led to the construction of ingenious instruments, by means of which the sphere of human vision has been extended to an extraordinary degree.

Apparatus of Vision.

Apparatus of Vision.

The apparatus of vision is composed of three distinct parts.

The *first* modifies the light.

The *second* receives the impression of that fluid.

The *third* transmits this impression to the brain.

The apparatus of vision is of an extremely delicate texture, capable of being deranged by the least accident. Nature has also placed before this apparatus a series of organs, the use of which is to protect and maintain it in those conditions necessary to the perfect exercise of its functions. Those protecting parts are the eye-brows, the eye-lids, and the *secreting* and *excreting* apparatus of the tears.

Protecting parts of the Eye.

The eye-brows, which are peculiar to man, are formed,

1. By hair, of a variable colour.
2. By the skin.
3. By *sebaceous* follicles placed at the root of every hair.
4. By muscles destined for their various motions, viz. the frontal portion of the occipito-frontalis, the superior edge of the orbicularis palpebrarum, the supercilium.
5. Numerous vessels.
6. Nerves.

* This interpetration pretty much resembles what is given of the vital powers; it may be true, but it explains nothing.

The eye-brows have many uses. The projection which they form protects the eye against external violence; the hairs, on account of their oblique direction, and the oily matter with which they are covered, prevent the perspiration from flowing towards, or irritating the surface of, the organ; they direct it towards the temple, and the root of the nose. The colour and the number of hairs of the eye-brows have an influence upon their use. They have generally some relation to the climate. The inhabitants of hot countries have them very thick and black; the inhabitants of cold regions may have them thick, but they are rarely black. The eye-brows protect the eyes from too much light, and particularly when it comes from above; this effect is rendered still stronger by knitting the brows. Use of the Eye-brows

The eye-lids are two in number in man, distinguished into superior and inferior, large and small; palpebra major, palpebra minor. The Eye-lids.

The form of the eye-lids is congruous to that of the globe of the eye, so that being brought together, they cover completely the anterior surface of this organ.

The place where they meet is not at the level of the transverse diameter of the eye; it is much below it: Haller committed an error in calling it *aequator oculi*. (16) The eye appears greater in proportion as the opening that separates the eye-lids is more extended: therefore, our opinion of the size of an eye is often incorrect; for the most part it expresses only the extent of the opening of the eye-lids. The moveable edge of the eye-lids is thick, and capable of resistance; provided with hairs of a greater or less length, more or less numerous, and of a colour generally resembling the hair of the head; these hairs are placed very close together.

Those of the superior eye-lid form a slight curve, the concavity of which is above; those of the inferior eye-lid form another curve in the contrary direction. There is an idea of beauty attached to those eye-lashes that are thick and long, and which agrees very well with their utility.

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(16) Haller merely says, that the upper palpebra is "*Paulo infrà* aequatorem oculi deducta," V. 315; obviously understanding, with our author, that the superior eye-lid extends below the middle *parallel circle, almicanther*, or *equator* of the eye. Criticism may consider herself more than usually fortunate, when she detects an anatomical blunder in Haller.

The eye-lashes are always covered with an oily matter, which proceeds from little follicles situated in the eye-lids, around the roots of the eye-lashes. This is commonly the case with all hair. Between the line occupied by the eye-lashes and the internal face of the palpebrae, there is a plane surface, upon which the eye-lids rest when they come in contact. I call this surface the *margin* of the eye-lid.

The eye-lids are composed of a muscle with semicircular fibres (*orbicularis palpebrarum*), of a fibrous cartilage, of a ligament (*ligament large de la paupiere*), (17) of a great number of sebaceous follicles (*glandulæ Meïbomii*), of a portion of mucous membrane. All these parts are tied together by a cellular tissue, generally lax and delicate, and which contains no fat.

Skin of the Eye-lids.

The skin of the eye-lids is very fine, and half transparent; it yields with great facility to their motions; it presents transverse wrinkles. The muscle of the eye-lids, in contracting, draws them together, or shuts the eyes, at the same time moving them a little inwards.

The fibrous cartilage of the eye-lids is called the Cartilage of the Tarsus; that of the superior eye-lid is much larger than that of the inferior. Their use is to keep the eye-lids extended, and in a position suitable to the form of the eye; they support likewise the eye-lashes, contain the *follicles of Meïbomius*, and protect the eye from external injury,

The use of the cartilage of the Tarsus does not appear indispensable, since some animals do not possess it, whose eye-lids, nevertheless, perform all their functions. What is called the *large ligament*, is only the cellular tissue, which extends from the base of the orbit to the superior edge of the Tarsus; it appears intended to limit the movement by which the eye-lids are brought together.

Cellulary Tissue of the Eye-lids.

The cellular tissue of the eye-lids is very fine and delicate, and contains no fat, but only a fine serous matter, in very small quantity, which in certain cases takes a little more consistence, and accumulates in the *areolae* of the tissue; the eye-lids are then swelled, and of a blueish colour. This colour and swelling of the eye-lids, are

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(17) Speaking of this imaginary ligament, Haller says, V. 321.—"Nunquam mihi certum definitumque a natura ligamentum visum est. Josias Weitbrecht omisit. Winslow attribuit sibi inventum."

observed after an excess of any kind, after great sickness, during convalescence, and in women during the time of the menses. The fineness and laxity of the cellular tissue of the eye-lids, the absence of the fat of its areolæ, are necessary for the free exercise of their motion. The ocular aspect of the eye-lids is covered by a mucous membrane.

Use of the Eye-lids.

Independently of the parts just mentioned, the upper eye-lid has a muscle which is peculiar to it, and which is called *levator palpebrae superioris.*

The eye-lids cover the eye during sleep, and preserve it from the contact of extraneous particles flying about in the air, which might injure it; they defend it from sudden shocks, by their almost instantaneous closure; and by their habitual motions, which are at nearly equal intervals, they preserve it from the effects of long continued contact of the air; they also moderate the force of a too brilliant light, and prevent the passage of any more of this fluid than what is necessary for vision, without offending the eye. On the contrary, when the light is feeble, we separate the eye-lids to a considerable distance, in order to permit the passage of as great a quantity of light as possible into the interior of the eye.

When the eye-lids are placed near each other, the eye-lashes admit only a small quantity of light to pass at a time. When the eye-lashes are humid, the little drops at their surface decompose the light, like the prism. The eye-lashes, by separating into pencils the light which penetrates into the eye, make bodies in ignition appear during the night as if they were surrounded with luminous rays. This appearance does not take place if the eye-lashes are inverted, or merely turned in another direction. It is also believed that the eye-lashes protect the eye from the small particles of dust that float in the air. The vision of those persons whose eyes have lost their eye-lashes, is always more or less imperfect.

Those compound follicles that are lodged in the substance of the Tarsus, are called Glands of Meïbomius.—They are very numerous; there are from thirty to thirty-six of them in the upper eye-lid, and from twenty-four to thirty in the lower. In every compound follicle, there exists a central canal, around which are placed the simple follicles, and into which they shed the matter which they secrete. This central canal is always full of that matter, which, in its ordinary state, is called the Liquor of Meïbomius, and Gum, when it is thick and dry. At the instant when one awakes, there is always a certain quantity of it accumulated at the great angle of the eye, and upon the borders of the eye-lids. This matter is believed to be of an unctuous nature; some particular researches make me think that it is essentially albuminous. Every central canal has an opening scarcely visible upon the internal surface of the eye-lid, very near its junction with the margin; these openings, placed very near to each other, continue all along the edge of this margin. The liquor of Meïbomius passes out by these openings, when the eye-lid is slightly pressed. As these openings suffer a sensible pressure in their advance along the anterior of the eye, it is probable that this pressure contributes to the secretion of the humour. It appears to me that the principal use of this humour is to facilitate the continual rubbing of the eye-lids upon the globe of the eye. The superior eye-lid pressing much more frequently upon the eye than the inferior, its follicles ought to be more numerous, and more considerable; and this is exactly the fact.

Lachrymal Apparatus.

Lachrymal Apparatus. The protection of the eye does not depend entirely upon the eye-brows and the eye-lids; there enters into the *tutamina oculi* a small apparatus for secretion, the mechanism of which is very curious, and of which the utility is very great. This is the apparatus for secreting the tears. It is composed of the lachrymal gland, of the secreting canals, of the *caruncula lachrymalis,* of the lachrymal conduits, and of the nasal canal.

Lachrymal Gland. The lachrymal gland, of small volume, is lodged in the little hollow that the concave of the orbit presents in its anterior and exterior part. Its use is to secrete the tears. This gland was known to the ancients, but they were not acquainted with its use; (18) they called it *glandula innominata superior,* in contradistinction to the caruncule, which they named *innominata inferior.* Some of them attributed the formation of tears to the caruncule, others to a gland

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(18) Its *use* was not unknown to the ancients. Galen de usu partium, lib. x. cap. II. p. 480, says :—"Two glands are formed in each eye: the one from the parts above, the other from the parts beneath, pouring out moisture into the eyes by *visible pores;*" &c., &c. The lower gland of Galen, who only dissected animals, is of course the *glandula Harderi.*

which does not exist in man, but only in certain animals. (*Glandula Harderi.*) (19)

Excretory Canals of the Lachrymal Gland.

The excretory canals of the tears are six or seven in number. They are produced from the little glandular grains, which by their union form the gland; they proceed some way in the intervals of the lobules which it presents; they soon quit it, place themselves upon the conjunctiva, and pierce this membrane very near the *Tarsus* of the superior eye-lid, towards its outer extremity.—They can be rendered visible by inflation, by raising up the superior eye-lid and compressing the gland, which causes the tears to flow through the orifices of the canals; by soaking the eye in water tinged with blood, and by injecting them with mercury. The tears are shed by these ducts at the surface of the conjunctiva. (20)

At the internal angle of the eye there is a projecting body, the rose colour of which indicates the *general energy of the force*, and the paleness of which, on the contrary, indicates a state of debility and sickness: this is the *caruncula lachrymalis.* This small body has, for the base of its composition, seven or eight follicles, which are ranged in a semicircular line, the convexity of which is in the inside. They have every one an opening to the surface of the *caruncula*; they contain each a small hair; these openings are disposed in such a manner, as to complete, with those of the glands of Meïbomius, a circle which embraces all the anterior part of the eye when the eyelids are separated.

At the place where the eye-lids quit the globe of the eye to direct themselves towards the *caruncule,* there is a small opening to be seen upon the internal face, near the open edge of each eye-lid; these are the puncta lacrymalia, the external orifices of the lachrymal canals. The

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(19) "Besides the lachrymal gland, several quadrupeds have an additional substance termed *glandula Harderi.* It exists in some of the *glires,* in the *carnivora, ruminants,* and *belluae.* In ruminants it is situated at the inner angle, and discharges a whitish humour which passes by an orifice under the *palpebra tertia.*"—*Fyfe Comp. Anatomy,* 59.

(20) The first accurate description of these ducts in man was published by the late excellent Dr. Monro, *secundus,* in his Anatomical and Physiological Observations, for 1758. The methods of demonstration here noticed by M. Magendie are those of Winslow, Lieutaud, and Cassebohm, who, as well as Dr. Hunter, are supposed by some to have anticipated Dr. Monro in this discovery.

lachrymal points are continually open; they are both directed towards the eye. They are supposed to be endowed with a contractile faculty, which should manifest itself upon their being touched by the extremity of a small instrument.—However careful I may have been in endeavouring to perceive those contractions, I have never succeeded: (21) and there is a circumstance here that may have given rise to deception. When one endeavours unsuccessfully to introduce a style, the mucous membrane, which covers the lachrymal points, becomes swelled by the afflux of the liquids, as it would do in any other point, and then the opening is lessened; it is necessary to distinguish this phenomenon from a contraction.

Lachrymal Canals.

By means of the lachrymal ducts, the openings which we have just mentioned lead to a canal which continues from the great angle of the eye to the lower part of the nostrils. The lachrymal canals are very narrow, they are about three or four lines long, and will scarcely permit the passage of a hair.

They are placed within the eye-lid, between the orbicular muscle and the conjunctiva; they open sometimes alone, sometimes together, into the upper part of the nose. Anatomists are mistaken in distinguishing two parts in the duct which extends from the great angle of the eye to the inferior meatus of the nasal fossae. This canal is nearly every where of the same dimensions, and the name of *lachrymal sac* ought not to be given to the upper part of it, reserving the name of nasal canal to the rest. Nevertheless, this canal is formed by the mucous membrane of the nostrils, which is prolonged into the bony conduit upon the posterior border of the ascending process of the maxillary bone, and the anterior half of the *os unguis*. Its use is to shed the tears into the nostrils.

The conjunctiva ought to be placed amongst the organs of the lachrymal apparatus; it is a membrane of the mucous kind which covers the posterior face of the eye-lids, and the anterior face of the globe of the eye. The loose manner in which it adheres to the eye-lids, as well as to the *sclerotica*, renders it particularly suitable to their motions. Does the conjunctiva pass before the transparent

(21) See more of this in Winslow's Anatomy, n. 282.—Haller suspects that he has mistaken the contractions of the orbicularis, and levator palpebrarum, for a proper irritability of the canals themselves, V. 331.

cornea, or does it stop at the circumference of this portion of the eye, and coalesce with the membrane which covers it? This has not been completely demonstrated. It is generally believed that it covers the cornea; but M. Ribes, a very distinguished anatomist, believes that the cornea is covered by a particular membrane, which is united to the conjunctiva by its circumference *without* being a continuation of it.—The conjunctiva protects the anterior surface of the eye; it secretes a fluid, which mixes with the tears, and seems to have the same use; it possesses an absorbent* power, supports the pressure when the eye is moved, and being always polished and humid, it gives much facility to motion. In short, it is this which sustains the contact of the air, when the eye is not covered by the stratum of tears of which we shall instantly make mention.

Of the Secretion of Tears, and of their uses.

This is not the place to describe the secretion of tears, to point out their similarity or their difference, with respect to other secretions; it is sufficient to understand, that the lachrymal gland forms them, and sheds them, by means of the conduits of which we have spoken, upon the conjunctiva at the external and superior part of the eye.(22) What happens after they arrive there we will endeavour to show. We would imagine that they ought to flow during sleep in a different manner than while awake. In this last state, the eye-lids meet and separate alternately; the conjunctiva is exposed to the contact of the air; the eye is continually in motion; nothing of all this exists during sleep.

* An animal can be poisoned by venomous matter applied to its conjunctiva. Hence I cannot agree with Mr. Adams (Sir W.), a celebrated oculist, of London, who thinks that the extract of Belladonna may always, and for a length of time, be applied to the eye with impunity.

[We must not throw away so valuable a remedy on the theoretical suggestion of our author: in this country, at least, no consequences, except the most beneficial, have ever been noticed from its external use.—T.]

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(22) It is evident that a considerable portion of the lachrymal fluid must be contributed by the mucous surface of the conjunctiva. The late Dr. Gordon was of opinion that only a very inconsiderable portion of this fluid is secreted by the lachrymal gland. It must be remarked, however, that the size and position of the gland seem perfectly commensurate to the office here attributed to it.

Physiologists suppose that the tears flow into a triangular canal, which carries them towards the great angle of the eye, where they are absorbed by the *puncta lacrymalia.*

They say that this canal is formed, 1st, by the border of the eye-lids, of which the *surfaces, round and convex,* touch only by a point; 2d, 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, added to the contraction of the orbicular muscle, of which the fixed point is in the ascending process of the maxillary bone, directs the tears towards the lachrymal points.

Excretion of Tears.

This explanation is defective. The eye-lids touch each other not upon a rounded edge, for their borders are planes; whence the supposed canal cannot exist. In fact, when the eye-lids are examined upon their posterior face, after they are shut, the line which indicates the point in which they touch can hardly be seen. Even admitting the existence of the canal, it could not be of any use except during sleep; it would then remain to be shown how they flow whilst one is awake.

Flowing of the Tears in sleep.

During sleep, and in every case in which the eye-lids are shut, the tears spread nearer and nearer upon all the surface of the conjunctiva, both of the palpebrae and eyeball; they should flow in greatest quantity in those points where they meet the least resistance. The direction in which the fewest obstacles are presented is the place where the conjunctiva passes from the eye to the eye-lids; in this direction they can easily arrive at the lachrymal points. The tears which are shed upon the conjunctiva should mix with the fluids secreted by this membrane, and be subject to the absorption which it exerts.

Flowing of the Tears while awake.

Things do not go on thus whilst we are awake. The portion of the conjunctiva which is in contact with the air, allows the tears which cover it to evaporate, and would become dry if the tears were not continually renewed by nictation. I believe this is the principal use of nictation. The tears, which are thus upon the part of the conjunctiva exposed to the air, spread themselves uniformly over the eye, and are the source of its brilliancy: the augmentation or diminution of this stratum has a considerable influence on the expression of the eyes; in looks of passion, for example, its thickness appears sensibly greater.

In the ordinary state of the secretion of tears, they do not in any manner tend to flow upon the external surface of the inferior eye-lid. I do not know upon what principle is founded the use generally attributed to the humour of Meïbomius, of opposing this overflow, much in the same manner that a little oil placed on the edge of a vessel prevents the overflowing of an aqueous fluid that rises above the level of it. I doubt the possibility of this humour being of such a use, for it is soluble in the tears. Use of the Humour of Meïbomius, relative to the course of the Tears.

The tears that are not evaporated, or not absorbed by the conjunctiva, are absorbed by the lachrymal ducts, and carried away into the inferior meatus by the nasal canal. (23) The manner of this passage is unknown. There have been explanations given of it, one after another, according to the theory of the syphon, of capillary tubes, of vital properties, &c.; these explanations are uncertain. The absorption of the tears by the lachrymal points is not at all evident, except when they are very abundant in the eyes. Absorption of the Tears by the Lachrymal Ducts.

Apparatus of Vision.

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

The position of the eye in the highest part of the body; the possibility of man perceiving one object with both eyes at the same time; the oblique form of the base of the orbit; the protection that the eye finds in this cavity against every external violence; the presence of a great quantity of adipose cellular tissue, which forms a sort of elastic cushion at the bottom of the orbit, &c.;—are so many circumstances that should not be neglected, but of which we can only make mention.

The eye is composed of parts which have very different uses in the production of vision. They may be distinguished into refractive, and non-refractive.

The refractive parts are:

A. The transparent cornea, a refractive body, convex and concave, which in its transparency, its form, and its insertion, pretty much resembles the glass that is placed before the face of a watch. Transparent Cornea.

(23) "How do the tears find their way into those passages?" said Dr. Gordon in his lectures,—"perhaps by capillary attraction; but this will not account for their motion within the sac."

B. The aqueous humour which fills the chambers of the eye; a liquid which is not purely aqueous, as its name indicates, but is essentially composed of water, and of a little albumen.

Crystalline Humour.

C. The crystalline humour, which is improperly compared to a lens. The comparison would be exact, were it merely for the form; but it is defective in regard to structure. The crystalline is composed of concentric layers, the hardness of which increases from the surface to the centre, and which probably possess different refractive powers. The crystalline is, besides, surrounded by a membrane, which has a great effect upon vision, as experience teaches us. (24) A lens is homogeneous in all its parts; at its surface, as in every point of its substance; it possesses every where the same refractive power. However, it is necessary to remark that the curve of the anterior surface of the crystalline is very far from being similar to that of the posterior aspect. This last belongs to a sphere, of which the diameter is much less than that of the sphere to which the curve of the anterior surface belongs. (25) Until now it has been understood that the crystalline was composed mostly of albumen; but according to a new analysis of M. Berzelius, it does not contain any: it is formed almost entirely of water, and of a peculiar matter that has a great analogy, in its chemical properties, to the colouring matter of the blood.

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(24) This is not a weighty objection. The acumen of M. Magendie may be turned to better account than the barren attempt of correcting anatomical comparisons, which are merely artifices of description, employed to assist the memory when it brings in review the irregular shapes of the animal organs. The geometer resolves his irregular figures into triangles or pyramids; but the anatomist, whose business is almost solely with external forms, cannot well employ these, and is therefore compelled to resort to comparison with other similar and known objects. Yet, as we only acquire new ideas by combining those which are old and familiar, it may be safely affirmed, that without the one or the other of these methods, anatomy, as a written science, cannot subsist; and the awkward attempt to introduce geometrical description, lately made by Dumas, may convince us how much preference is due to the method of comparison. Were the things compared *entirely* alike, this process would cease to be comparison, it would merely express identity; but, since resemblance only is wanted, it would not be difficult to show that the comparison of the figure of the crystalline humour to a lens, is probably the most accurate similitude to be met with in all anatomy.

(25) The diameter of the anterior curve is to the diameter of the posterior curve, as 7.5 : 5 (Petit), or 33081 : 25056 (B. Martin).

D. Behind the crystalline is the vitreous humour, so called because of its resemblance to melted glass.*

Each of the parts which we have noticed is enveloped by a very thin membrane, which is transparent like the part that it covers: thus, before the cornea is the conjunctiva: behind it is the membrane of the aqueous humour, which lines all the anterior chamber of the eye; (26) that is, the anterior surface of the iris, and the posterior surface of the cornea. **Membrane of the Aqueous Humour.**

The crystalline is surrounded by the crystalline capsule, which adheres by its circumference to the membrane that covers the vitreous humour. This, in passing from the circumference of the crystalline upon the anterior and posterior surfaces of this part, leaves between an interval, which has been called, the *canal goudronné*. (27) Hitherto it has not been supposed that this canal communicated with the chamber of the eye: but M. Jacobson asserts that it presents a great number of little openings by which the aqueous humour can pass out or enter. We have endeavoured to find these openings, but without success. **Crystalline Capsule.** **Canal Goudronné.**

The vitreous humour is also surrounded by a membrane called *hyaloid*. This membrane does not alone contain this humour, it is sent down amongst it, and separating, forms it into cells. The details of anatomy, with regard to the disposition of these cells, have not hitherto added any thing to what is known of the use of the vitreous humour. (28) **Hyaloid Membrane**

* According to M. Berzelius, the vitreous humour contains of water 98.40.; albumen, 0.16.; muriates and lactates, 1.42.; soda, with an animal matter soluble in water alone, 0.02.; total, 100.0.

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(26) The existence of this membrane of the aqueous humour appears still to be extremely ambiguous. Edwards thinks he has traced it as it passes between the layers of the choroid and the iris proper.

(27) In this country it is named the canal of Petit. Bertrand, p. 73, conceives that he has seen the water of the *vitreous* humour transuding into it; and Camper, from a theory, fancied it to be occasionally distended with electric matter, and thus to accommodate the lens to the different distances of objects. Haller, El. Phys. V. p. 394, l. 51. Hence was probably derived Dr. Edwards' theory of adaptation given below.

(28) The following measures of the eye in tenths of an inch, are given, "from actual measurement in a great number of human eyes, with the greatest care and exactness, as follows," by the celebrated optician, Mr. Ben. Martin, *Phil. Brit.* I. 253:—

	Tenths.
Diameter of the eye from outside to outside, - - - - - -	9,4
Radius of convexity of the cornea, - - - - - - - - - -	3,3294

The eye is not only composed of parts that are refractive, but it is composed also of membranes which have each a particular use; these are:—

Sclerotic. A. The sclerotic, the exterior envelope of the eye, which is a membrane of a fibrous nature; it is thick and resisting, and its use is evidently to protect the interior parts of the organ; it serves besides as a point of insertion for many muscles that move the eye.

Choroid. B. The choroid, a vascular and nervous membrane, formed by two distinct plates; it is impregnated with a dark matter which is very important to vision.

Iris. C. The iris, which is seen behind the transparent cornea, is differently coloured in different individuals; it is Pupil. pierced in the centre by an opening called the *pupil*, which dilates or contracts according to certain circumstances which we shall notice. The iris adheres outwardly, and by its circumference, to the sclerotic, by a cellular Ciliary Ligament. tissue of a particular nature, which is called the *ciliary*, or *iridian* ligament. There are, behind the iris, a great number of white lines arranged in the manner of rays, which would unite at the centre of the iris, if they were Ciliary Processes. sufficiently prolonged: these are the *ciliary processes*.

Neither the use nor the structure of these bodies has been properly determined: they are believed by some to be nervous, by others to be muscular, whilst others think them glandular, or vascular. The truth is, their real structure is not understood. We will see, on proceeding a little farther, that the case is the same as to their use.

Colour of the Iris. The colour of the iris depends on its structure, which is variable, and on that of the dark layer of its posterior surface, the colour of which shines through the iris. For instance, the tissue of the iris is nearly white in blue eyes; in this case the dark colour behind appears almost alone, and determines the colour of the eyes.

Anatomists differ about the nature of the tissue of the

	Tenths.
Radius of convexity of anterior surface of the lens, - - -	3,3081
Radius of convexity of posterior surface of the lens, - - -	2,5056
Thickness of the lens (*anterio-posterior axis*), - - - - -	1,8525
Thickness of the cornea and aqueous humour together, - -	1,0358

Specific gravity of lens to water as - - - - - - -	11 to 10
Refraction at the cornea is as - - - - - - - - - -	4 — 3
Refraction at the anterior surface of the lens as - -	13 — 12
Refraction at the posterior surface of the lens as - -	12 — 13

iris : some think it entirely like that of the choroid, essentially composed of vessels and of nerves ; others have imagined they saw a great many muscular fibres in it ; others consider this membrane a tissue *sui generis ;* and others confound it with the *erectile* structure. M. Edwards has shown that the iris is formed by four layers very easy to be distinguished, (29) two of which are a continuation of the laminæ of the choroid ; a third belongs to the membrane of the aqueous humour ; and a fourth forms the proper tissue of the iris.

Between the choroid and the hyaloid there exists a membrane essentially nervous. This membrane, known by the name of the retina, is almost transparent ; it presents a slight opacity, and a tint feebly inclining to *lilac ;* it is composed of the expansion of the threads which compose the optic nerve. M. Ribes does not consider it as such ; he thinks that it forms a particular membrane in which the branches of the optic nerve are distributed. He then establishes an analogy between the retina and the other membranes.—The retina presents, about two lines outwardly from the entrance of the optic nerve, a yellow spot, (*Tache jaune*) and beside it a number of folds. These appearances are found only in man, and in some apes. (30) Retina.

(29) The arguments against the muscular tissue of the iris are of great weight. The most vehement stimulus, the puncture of a needle, the incision and laceration produced by the surgeon's knife and scissars, are incapable of occasioning the least contraction; an effect, indeed, which seems to be solely determined by the state of the retina or optic nerve. Even its fibrous texture has been disputed by such grave authority, and is so invisible to ordinary eyes, in all animals, (Knox, *Ed. Phil. Trans.* 1823, p. 29,) that granting this structure to be a proof of muscularity, which it is not, the irritable nature of the iris cannot with fairness be deduced from it. Indeed, if M. Edwards can demonstrate his anatomy of its layers, as given in the text, the question is decided, for as to the contraction and dilatation of the pupil of the iris, so much insisted on by authors, that phenomenon ought no more to be referred to proper irritability, than the contraction and dilatation of the urethra, in the corresponding state of erection and collapse of the surrounding penis. Both are probably the result of temporary congestion of blood, at least both admit of being explained in this way, without doing any violence to our established notions of myology, or to the evidence of our senses. A muscle which should be incapable of being stimulated of itself, though easily affected through other organs, affords a tempting paradox : but such ornaments ought to be added to science with a sparing hand; and the *Nec Deus intersit nisi dignus vindice nodus inciderit,* is not less applicable to a paradox than to a new hypothesis.

(30) This yellow spot or central hole of Soemmering, as has been lately discovered by the learned and ingenious Dr. Knox of this city, exists in

Vessels and Nerves of the Eye.

The eye receives a great number of vessels, (the *ciliary arteries and veins*) and many nerves, the greater part of which come from the *ophthalmic ganglion.*

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several of the lizard tribe, as the L. *superciliosa, scutata, striata, calotes;* as also remarkably distinct in the chameleon, which he did me the favour to show soon after he had discovered it. The lizards named *gecko, mabuya,* &c., he has ascertained to want this feature of approximation to the human race. See *Edin. Phil. Trans.; Mem. Wern. Soc.*, V. Part I. The late Dr. Gordon, in whose premature death this curious subject was deprived of an enthusiastic inquirer, endeavoured, in company with Dr. Brewster, to ascertain whether this was really an aperture or merely a *yellow spot;* and his conclusions were favourable to the former. The experiments consisted in insinuating air behind the retina, and observing whether, when gently pressed, it issued by the foramen centrale, which it generally did. Dr. Knox has, I believe, repeated the experiment, and seems likewise to incline to the same opinion. Man, then, some quadrumana, and many lizards are furnished with this singular structure; and the student will not forget that it is always situated on the very point where the axis of the eye falls upon the retina, and that its magnitude is sufficiently ample to receive a great proportion of all the images that fall on the latter. The image of the wing of a windmill, 6 feet in length, when seen at the distance of 12 paces, measures only 1-20th of an inch upon the retina.—Hall. V. 476. It would seem to follow from hence, that images are not imprinted on the retina, but its subjacent membrane, in the above animals, possessing this central aperture. Are we then to resume with Mariotte, Lecat, Clairault, Euler, and the heterodox of the old school, that the choroid is the true seat of vision, at least in these animals; and that this perforation is merely destined to permit the concentrated light of the image to impinge upon a larger surface? The concentrated light which constitutes the image is capable of producing vision both anterior and posterior to the absolute focal point, for a greater distance than the depth of Soemmering's hole, but the intensity of effect will evidently be proportionate to this depth, supposing that the choroid is at all capable of perceiving light. But it is not necessary to assume this. The air employed by the above-mentioned philosophers may merely have escaped by rupture of the invisible tenuity to which the retina is here confessedly reduced. This fine web may still line the central hole, and, in that case, the use of the excavation can easily be comprehended: it increases the surface acted on, and consequently the intensity of effect produced by the image. Why it should be found in so remote a race as the lizard, is a problem for the naturalist. Between the choroid and hyaloid, according to Dr. Jacobs of Dublin, there are found *two* membranes, the one the retina described by our author, the other a very fine serous membrane, covering the retina from the optic nerve to the ciliary processes. Its inner surface is not tinged by the pigmentum nigrum, though Dr. Knox (l. c.) supposes that in animals it is the proper membrane of this pigment, but presents a clear white appearance, which Haller has properly enough compared to snow. El. Phys. V. 385–393. But though Haller and Zinn had evidently seen this membrane, its accurate description, and an elegant mode of demonstrating it, are certainly due to the exertions of Dr. Jacobs, who prepares it not in patches, as seen by Haller and Zinn, but in one unbroken concave shell, corresponding to the form of the vitreous humour.—(*Phil. Trans.* 1819. *p.* ii. *p.* 300–307.)

Optic Nerve.

This nerve preserves the communication between the brain and the eye. (31) It does not come from the optic thalamus, as many anatomists imagine; it originates—1st, from the anterior pair of the *corpora quadrigemina;* 2d, from the *corpus geniculatum externum,* a prominence which is seen a little before, and without these tubercles; 3d, and lastly, from the lamina of grey substance placed between the adhesion of the optic nerves at the mamillary eminences, and which is known by the name of *tuber cinereum.* The two optic nerves approach each other, and appear to join upon the superior aspect of the body of the sphenoid bone. There have been many endeavours made to determine if they cross each other, if they merely lie upon one another, or if they completely mix and become confounded;—this question has not yet been solved. Pathology affords evidence in favour of all these opinions: thus the right eye being long wasted, the optic nerve has been seen on the same side likewise wasted in its whole length. In other cases in which the right eye was destroyed, the anterior portion of the nerve of the same side has been seen in a state of evident decay, and the posterior portion of the left nerve exactly like it. Some have thought that the crossing of the optic nerves which takes place in the eyes of fishes, is sufficient to remove every doubt; but this, at the most, furnishes only a probability. Optic Nerve.

The optic nerve is not formed of a fibrous envelope, and of a central pulp, as the ancients supposed; it is composed of very fine threads placed side by side, and communicating with each other like the other nerves. This disposition is very evident in that portion of the nerve which extends from the *sella turcica* to the globe of the eye. Structure of the Optic Nerve.

Mechanism of Vision.

In order the better to explain the action of light in the eye, let us suppose a luminous cone commencing in a point placed in the prolongation of the *anterio-posterior axis* of the eye. We see that only the light which falls upon the cornea can be useful for vision; that which falls on the white of the eye, the eye-lids and eye-lashes, contributes Mechanism of Vision.

(31) See Gordon's Anat. I. p. 88. Duncan's Med. and Surg. Journal, v. 52-3-4-5.

nothing; it is reflected by those parts differently according to their colour. The cornea itself does not receive the light on its whole extent; for it is generally covered in part by the border of the eye-lids.

Use of the Cornea.

Use of the transparent Cornea.

The cornea having a fine polish on its surface, as soon as the light reaches it, part of it is reflected, which contributes to form the brilliancy of the eye. This same reflected light forms the images which one sees behind the cornea. In this case the cornea acts as a convex mirror. The form of the cornea indicates the influence it should have upon the light which enters the eye: on account of its thickness, it only causes the rays to converge a little towards the axis of the pencil; in other words it increases the intensity of the light which penetrates into the anterior chamber.

Use of the Aqueous Humour.

Use of the Aqueous Humour.

The rays, in traversing the cornea, pass from a more rare to a denser medium; consequently they ought to converge from the perpendicular towards the point of contact. If, on entering into the anterior chamber, they passed out again, they would diverge as much from the perpendicular as they had converged before; and would, therefore, assume their former divergence; but as they enter into the aqueous humour, which is a medium more refractive than air—they incline less from the perpendicular, and consequently diverge less than if they had passed back into the air.

Of all the light transmitted to the anterior chamber, only that which passes the pupil can be of use to vision; all that which falls upon the iris is reflected, returns through the cornea, and exhibits the colour of the iris.

In traversing the posterior chamber the light undergoes no new modification, as it passes always through the same medium (the aqueous humour).

Uses of the Crystalline Lens.

Uses of the Crystalline

It is in traversing the crystalline that light undergoes the most important modification. Philosophers compare the action of this body to that of a lens, the use of which would be to assemble all the rays of any cone of light upon a certain point of the retina. But as the crystalline is very far from being like a lens,* we merely mention this opinion, which is generally received, to remark that it merits a fresh investigation. Every thing positive which can be said on the subject is, that the crystalline ought to increase the intensity of the light which is directed towards the bottom of the eye, with an energy proportionate to the convexity of its posterior surface. It may be added, that the light which passes near the circumference of the crystalline is probably reflected in a different manner from that which passes through the centre;† and that therefore the contraction and dilatation of the pupil ought to possess an influence upon the mechanism of vision, which deserves the attention of philosophers.

Use of the dark matter which covers the posterior surface of the iris.

The whole of the light which arrives at the anterior surface of the crystalline, does not penetrate into the vitreous body; it is partly reflected. One part of this reflected light traverses the aqueous humour and the cornea, and contributes to form the brilliancy of the eye; another falls upon the posterior surface of the iris, and is absorbed by the dark matter found there.

It is probable that something of this sort happens at every one of the strata or layers which forms the crystalline.

Uses of the Vitreous Humour.

Use of the Vitreous Body.

The vitreous body possesses a less refractive power than the crystalline; consequently the rays of light which, after having passed the crystalline, penetrate into the vitreous body, diverge from the perpendicular at the point of contact.

Its use then, with regard to the direction of the rays in the eye, is to increase their convergence. It might be said, that in order to produce the same result, nature had only to render the crystalline a little more refractive; but the vitreous humour has another most essential use, which is, to give a larger extent to the retina, and thus to increase the field of vision. (32)

* See page 34.

† The structure of the crystalline may perhaps have the effect of correcting that aberration which is always produced by the sphericity of ordinary lenses.

(32) A pencil of rays transmitted through a lens can only arrive at a focus in some point of their own axis, which necessarily passes through the centre of the lens; and since no two pencils can have the same axis,

What we said about a cone of light, commencing in a point placed in the prolongation of the anterio-posterior axis of the eye, must be repeated for every luminous cone commencing in other points, and directed towards the eye; with this difference that, in the first case, the light tends to unite at the centre of the retina; whilst the light of the other cones tends to unite in different points, according to that from which they commence. Thus the luminous cones commencing from below, unite at the upper part of the retina, whilst those that come from above, unite at the lower part of this membrane. The other rays follow a direction analogous; so that there will be formed at the bottom of the eye an exact representation of every body placed before it, with this difference, that the images will be inverted, or in a position contrary to that of the objects they represent.

This result is ascertained by different means. For this purpose, eyes, constructed artificially of glass, which represent the transparent cornea, and the crystalline; and of water, which represents the aqueous and vitreous humours, have long been employed. There was another method generally in use before the publication of my memoir upon the images which are formed at the bottom of the eye. It consists in placing in the window shutter of a dark chamber the eye of some animal, (as of a sheep or an ox,) taking care to remove the posterior part of the sclerotic. (33) The images of objects placed so as to send rays back to the pupil, are then distinctly seen upon the retina.

The same process was known to Malpighi, and to Haller.* There is another which is peculiar to myself, which is in employing the eyes of *albino* animals, such as those of white rabbits, white pigeons, white mice, (perhaps the eyes of *albino* men might be suitable for this purpose.) These eyes present the most favourable conditions for the success of this experiment; the sclerotic is very thin in

* El Phys. v. 469.

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these lines must necessarily decussate, at, or near the centre of the lens, and thus invert the image.

(33) The experiment was known to Kepler, Newton, Des Cartes, his follower Rohault, to Hook also, and probably to much earlier authors. It is the foundation of all our theories and doctrines of vision, whether good or bad.

them, and almost completely transparent; the choroid is equally thin, and as soon as the animal is dead, the blood from which it derived its colour disappears; it then can present no sensible obstacle to the passage of the light. The clearness and facility with which the images are seen in following this process, suggested to me an idea of making some experiments for the purpose of invalidating or confirming the theory which is generally admitted with respect to the mechanism of vision.

If there be a small opening made in the transparent cornea, by which a small quantity of the aqueous humour is made to pass out of the eye, the image is no longer so distinct; the same thing happens if a small quantity of the vitreous humour is pressed out of the eye by a little incision in the sclerotic; this proves that the proportions of the aqueous and vitreous humours are in a certain relation to the perfection of vision.

I have endeavoured to determine the law of the dimensions of the image relatively to the distance of the object: I have found that the size of the image is sensibly proportional to the distance. M. Biot assisted me in the verification of this result, which otherwise agrees with that given by Lecat in his *Treatise of Sensations*. (This author employed artificial eyes in his researches.)

Experiments on the images formed in the eye.

I made a small opening in the circumference of the transparent cornea, near its junction with the sclerotic, and drew out all the aqueous humour by this aperture; the image (a burning taper) appeared, every thing else being the same, to occupy a greater space upon the retina; it was much less defined, and less intense than the image of the same object, seen in the other eye of the animal, which I had placed in a relative position as to the taper, but which had been preserved entire for the purpose of comparison:—this is exactly in unison with what we said as to the use of the aqueous humour in vision.(34)

(34) In these ingenious and beautiful experiments, there is less novelty than our candid author has been led to imagine. The only advantage derived from employing the eyes of albino animals, is the transparency of the membranes, which seems to have been sufficiently appreciated by Haller: "Denique in noctuae oculo etiam integro, inspiciendo, objecta corpora in retina depicta apparent, quia *sclerotica posterius pellucet*. Ipse experimentum repetii."—V. 469. It is pleasing to find such high authority in confirmation of our author, and the experiments which follow, would have called forth the loudest praise from the great man we quote, had he

The same thing happens with regard to the cornea; if it is entirely removed by a circular incision made at the union of this membrane with the sclerotic, there is no change in the dimensions of the image, but the light loses much of its intensity.

We observe that the size of the opening of the pupil has probably an influence upon the mechanism of vision. After having removed the cornea, the pupil can be easily enlarged by a circular incision in the tissue of the iris. In this case also the image becomes enlarged. As the use of the crystalline is to increase the brightness and perfect form of the image, in diminishing its size, it might be supposed that the absence of this body would produce a contrary effect. When, by an operation like that of cataract, the crystalline has been extracted from the eye, the image is still formed at the bottom of the eye, but considerably increased; it becomes four times as large as that formed by a perfect eye, the other conditions being the same; in other respects it is very ill defined, and the light which produces it is very feeble.

Experiments on the images formed in the eye.

If from the same eye the aqueous humour, the crystalline, the transparent cornea, are taken away; and only the crystalline capsule, and the vitreous humour are left for *media*, there is no longer any image formed in the retina; the light passes through to it very well, but there is no appearance of form.

The most of these results agree sufficiently with the theory of vision, as at present received. There is, however, one exception, which is the perfectness of the image. In theory, whatever is the distance of the object, the eye ought to change its form in order to produce a perfect image, or else the crystalline be carried forwards or backwards according to the distance.* But here experience

* These changes in the form of the eye, or in the position of the crystalline lens, have been successively ascribed to compression of the globe of the eye by its muscles, to contraction of the lens, of the ciliary processes, &c. Of late, M. Jacobson has ascribed them to the entry or exit of water from the canal of Petit.

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lived in our age. They are experiments which establish the fundamental principles of optics, and must in future form an almost necessary part of every severe legitimate demonstration of the laws of vision.

is contrary to theory, which renders all the explanations which have been proposed on this subject of no avail. (35)

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(35) It is nothing singular to find our well-informed author arranging himself with almost the whole race of physiologists, in maintaining that an adaptation of the eye, to the distance of the object, is necessary, in theory, at least, to distinct vision. This notion, of which we shall endeavour to demonstrate the fallacy in a few words, has evidently been derived from the changes which are observed to take place when the image of a candle passing through a single lens is received upon a plane. But, though the light of a candle may soon be withdrawn to a distance so great, that its diverging light does not much surpass in intensity its parallel light, nor even the light thrown into the unprotected lens, or the recipient surface, from illuminated objects around; so that the formation, or, at least, *our perception* of a distinct image, becomes impossible: the case is far different with the human eye. The human eye is not a mere plane, furnished with a lens set at a definite distance before it, and which, by receiving light from all the hemisphere around it, can only exhibit an image transmitted by its lens, when that image is more intense than the light already on its surface. *The human eye is a camera obscura, and, like it, receives the image of every object accurately at every distance.* If, in these latitudes, we turn the lens of the camera obscura to the south, that is, towards the region of most intense light, the images on its table disappear: Why? Merely because a light stronger than that which formed the picture, is now reflected from the table, and, by its superior intensity, takes the place of the picture in our eye, but does not at all efface the picture on the table; it merely renders it invisible to us, as the sun does the moon and stars in the day time. If, by descending into a deep pit, we withdraw our eye from his rays, the stars again appear in all their glory: by revolving the lens of the camera to the northern aspect, the pictures are again seen on the table as fresh as ever. Even the intense image of a candle formed upon paper by a convex lens, is effaced by another candle held near it. The eye, and the camera obscura, are defended from the influence of external light, and it is this defence which constitutes nearly the whole difference of their phenomena from those of the naked lens.

1. This being premised, let the reader imagine a body, as an arrow, placed at the distance in which its image is distinctly formed on the retina by concentration of *some* of its rays. Next, let it be removed to any distance from the eye,—say double. It is evident that many of the rays of the pencil, that were concentrated into the focus in the last image, cannot now meet in that focus again, since their angle of incidence at the lens is now entirely changed; but affecting a more distant focus, they will illuminate the image and the space around it, and thus render it indistinct: and if no other rays issued from the arrow, it would now be scarcely visible. *But an infinity of other rays flow from the arrow in all directions*, and consequently there will still be found a *sufficient number* of its rays which form the same angle of incidence with the lens, as many of the rays of the former pencil did; and consequently are concentrated, as before, into the focus upon the retina, there to constitute an image of the arrow perfectly similar to the former, but fainter in the duplicate ratio of the distance. But independently of the oblique rays, there is always an image formed exactly upon the retina by the parallel rays, namely, by those rays which flow from the surface of every visible object in a direction parallel to each

It would be erroneous, however, to suppose, that things happen exactly the same with the eye of a living, as with

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other, and either perpendicular or oblique to the segmental plane of the cornea. By an easy, obvious, computation from the table we have given of the dimensions, &c., of the parts of eye, Martin has demonstrated *that* THESE *rays must always form an image exactly upon the surface of the retina*, whatever be the distance of the luminous object. (*Ph. Br. II.* 255.) In all considerable distances, the two images thus formed, by the parallel and oblique rays respectively, will coincide, in size, form, and colour. Nay, there is a third image which would be formed equally on the same point of the retina, if the lens were totally removed; it may be called the *image of aperture*. This image takes place in the camera obscura, or in any dark chamber facing to the north, and furnished with a small aperture to admit the light, the pictures of external bodies being thereby formed only a little less distinctly than when transmitted into it by a lens. The lens, by concentrating the light, merely increases the intensity of the image seen in the camera obscura, and adds a few cross rays which would otherwise have been lost to it. Now, as the eye is a perfect camera obscura, all these three images must be taken into account in considering the effect of distance upon the visual image: for though the lens certainly modifies the *parallel* and *apertural* images, they obey peculiar laws, frequently beyond the reach of its influence. Nay, it must now be asked, whether the apertural image may not before, as after cataract, be sufficiently modified by the variations of the pupil to answer most of the purposes of vision? whether the image at the bottom of the eye be not always, as Martin thinks, the *parallel* image? or rather a compound of the *parallel* and the *diverging?* It must be observed that, in a pencil of diverging rays, there are rays of every possible angle of incidence from the extreme ray to the perpendicular itself; and that as this must be the case at every distance, till *optical* infinity, when they become parallel, every distance has the means of forming a sufficient image at the same focal distance: and that though mathematicians have not erred in their theorem (*Simpson's Algebr.* 312.) for finding the focal distance for a *single oblique ray*, which they conceive to recede along the visual axis, yet Physiologists have been greatly mistaken in their application of this conclusion to a body which emits many pencils making the same progress, and transmits its rays through a contractile aperture into a *camera obscura*. The argument holds for any other distance; and it is clear that the eye, independently of all adaptation, receives a perfect focal image of every object at every distance. What, then, is the use of adaptation?

2. M. Magendie's experiments, as he confesses, prove that this is actually the case in the human eye, namely, that the image is alike perfect at every distance, though not alike luminous.

3. In the camera obscura, the images are all perfect, though luminous in the subduplicate ratio of the distance: yet in that instrument no adaptation is ever employed. That on the Caltonhill of Edinburgh, shows objects distinctly for many miles around.

4. When we want to see an object distinctly, we bring the eye nearer or farther from it, according to its degree of illumination; whereas, if the eye had in reality the power of accommodation ascribed to it, we would surely employ it on such occasions to save ourselves all this trouble; nay more, that effort which has been mistaken for it, is really employed, at least as far as the muscles are concerned, at the same time that we advance or recede.

that of a dead animal. In the living animal there is a very great difference, which is, that the pupil dilates or contracts according to the intensity of the light, and perhaps according to the distance. Observation teaches us that when the object is much illuminated, the pupil contracts so much that the opening of it is scarcely visible, which cannot fail to diminish the image. But, on the contrary, when the object is very little illuminated, the pupil becomes very much dilated, which ought to produce a considerable increase of the image.

Motions of the Iris.

Some say that the pupil varies its dimensions according to the distance of the object. This fact has not been sufficiently demonstrated: hitherto the influence of the intensity of light is the only thing that has been correctly observed. Motions of the Iris.

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5. When we look through a card perforated by two holes, we see the object only at the point of distinct vision: but double at every other single distance, thus clearly showing that there is a certain and definite distance at which the eye can see distinctly, but that the eye possesses no power of producing this distinct vision when the object is placed at any other distance.

6. Even the contraction of the pupil, though it assists our vision of distinct objects, is not absolutely necessary, since Daviel has shown that patients having the pupil immovable see well enough.

7. Persons who have had the lens removed for cataract, still see sufficiently well: though it is evident that in them any apparatus of accommodation adapted to the action of the lens must be useless; and we cannot grant an apparatus for changing the other parts, which are so inefficient while the lens is present in the eye.

8. The effort (*Young Nat. Phil.* I. 450.) by which the eye is supposed to see distinctly, is nothing foreign to the effort we employ when endeavouring to hear or feel distinctly: we direct the mind to the part, or to be less figurative, we endeavour to attend exclusively to the sensation present in the eye, which is thus rendered more perfect, merely by the exclusion of other previous, or contemporaneous sensations, for the time. The proof of this is clear: we employ the same effort in looking at the stars, which send only parallel rays; we employ it energetically, though, quite fruitlessly, to behold objects placed within the nearest limit of distinct vision; and when we find we cannot help ourselves, we resort to glasses, or withdraw the head to a proper distance. On the whole, unprejudiced consideration of the above will show that theory, experiment, and observation, are decidedly hostile to the theory of adaptation; and that philosophers have clung to this venerable bubble as they long did to their beards, from a seemingly systematic aversion to every thing common or familiar. They must have known that long since the immortal Haller had boldly exposed its nakedness; but he seems either to have been little read, or not to have been understood by many of his successors. *See V. P.* 516. *of El. Physiol.*

Physiologists have been much employed about the mechanism which produces the motion of the iris: some have admitted the existence of muscular fibres, and have by their action explained the motions of this membrane; others have considered them as of a particular nature. Mery and Haller have supposed this phenomenon to have a relation to that of erection. According to them, the motion of the iris is excited in a sympathetic manner, by the action of the light upon the retina.

Lately, M. Maunoir, of Geneva, has recognized in the iris two strata of fibres; the one of which he calls *radiant*, and which occupies the circumference of the iris; the other he calls *pupillary muscle*, which is irregularly concentric, and forms the centre of the membrane. M. Maunoir considers these fibres as muscular; but he brings no sufficient proof to the support of this opinion.*

There have been individuals, it is said, who possessed the power of directing the motions of the pupil according to their will; and naturalists relate that a number of birds, such as parrots, night birds, &c., present this phenomenon.

A stream of light directed upon the iris determines no motion, which appears to prove, that the nerves of this part belong to the system of the *ganglions*.

The *section* of the iris, in certain operations, is not painful; it has, however, been followed by vomitings.

The irritation of the iris by the point of a *cataract needle* causes no sensible motion in this membrane, as I have found by experience.

M. M. Fowler and Rinhold have found that the galvanic excitation, directed upon the eye of man and of animals, causes the contraction of the iris. Doctor Nysten has also proved the same upon the bodies of malefactors, upon which the experiment was made a short time after death. But must we conclude, according to the above-mentioned authors, that the motions of the iris ought to be considered as muscular motions? I do not think so. In these experiments the retina, as well as the iris, has been sub-

* Individuals weakened by venereal excesses, or labouring under tabes mesenterica, worms, or hydrocephalus, have the pupil enlarged: narcotic plants, particularly belladonna, applied for some hours on the conjunctiva, dilate the pupil: in cerebral affections, it is sometimes contracted, sometimes dilated. Its motions, in general, indicate the state of sensibility in the retina. The consideration of these, and of its state, are peculiarly serviceable in medicine.

jected to the galvanic current; and there has been nothing to prove that the contraction of the iris was not the effect of the irritation produced on the retina.

Uses of the Choroid Membrane.

Uses of the Choroid.

The choroid is of use to vision, principally by the dark matter with which it is impregnated, and which absorbs the light immediately after it has traversed the retina. One may consider, as a confirmation of this opinion, what happens to some individuals in whom some parts of this membrane become *varicose:* the dilated vessels throw off the dark matter which covered them, and every time that the image of the object falls upon the point of the retina corresponding to these vessels, the object appears spotted with red.

The state of vision in Albino men and animals, in which the choroid and the iris are not coloured black, supports still more this assertion; vision is extremely imperfect in them: during the day, they can scarcely see sufficiently to go about.

Mariotte, Lecat, and others, have allowed to the choroid the faculty of perceiving light. This idea is completely without proof.

Uses of the Ciliary Processes.

We know very little, that is certain, of the ciliary processes. They are generally supposed *contractile* (36) but

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(36) Our author seems to have been misled on this point; no good physiologist of the present day maintains the contractility of the ciliary processes. It was, indeed, a favourite notion of Kepler, and afterwards of Dr. Porterfield, that they dragged forward the crystalline lens to a less distance from the cornea. But Haller and Zinn showed that they are not muscular; and though Zinn fancied they might act by erection, as they seem cellular in some animals, the doctrine of their contractility is completely exploded. Could they contract at all, or had they a firm enough attachment to the capsule of the lens, and this in man they have not, they would, in reality, drag the lens *backward,* not forward, as Kepler and Porterfield, in despite of anatomy, imagined.—*See La Charriere,* 284; *Perrault,* 579; *Hartsoeker,* 76; *Brisseau,* 77; *Monro tertius, Outl.* III. 146; *Knox, in Ed. Phil. Trans.* 1823, where he asserts the presence of "semipellucid fibres, extending from the equatorial edge of the lens, over the canal of Petit, to the folds between the ciliary processes, which they conjoin with the lens." He has omitted to state explicitly whether these are visible in man, or only in animals.

some think that they are destined to the motions of the iris, whilst others imagine they are intended to bring forward the crystalline. Their use, according to M. Jacobson, is to dilate the openings, which he pretends the *canal of Petit* presents anteriorly, so as to give an entry into this canal to a portion of the aqueous humour, the result of which would be to displace the crystalline. There are also some persons who believe that the ciliary processes are the secreting organs of the dark matter of the posterior face of the iris and the choroid, or even of a part of the aqueous humour.

Mr. Edwards has announced, in a memoir upon the anatomy of the eye, that they contribute principally to the secretion of the aqueous humour.* M. Ribes has given the same opinion; he adds that the ciliary processes support life and motion in the crystalline, and vitreous humour. There are, however, animals that have no ciliary processes, and in which these humours exist. Haller thinks that their use is to maintain the crystalline in the most advantageous position. According to this anatomist, they adhere to the crystalline capsule both by the point and by the posterior side, by means of the dark matter with which they are covered.

Action of the Retina.

Action of the Retina.

If we here treat of the action of the retina by itself, it is to facilitate the study of this function; in reality the action of this part cannot be separated from that of the optic nerve, and still less from the action of the brain. The action of the retina is a vital action; the mechanism of it is completely unknown.

The retina receives the impression of light when it is within certain limits of intensity. A very feeble light is

* The celebrated Dr. T. Young, of London, has published a similar opinion, some years ago.—See the Philosophical Transactions. (37)

(37) Dr. Young has also laboured much to establish a notion, first advanced by Dr. Pemberton (1719), and afterwards by others, that the lens is muscular. It is no doubt fibrous, and this, if it had been doubtful before, he has clearly established; but there appears no proof of its irritability and contractility, the two essential characters of muscular structure. It may be doubted, whether the fibrous texture is necessary to muscularity, and certainly a body may be fibrous without being muscular.—*See Young's Nat. Phil.* II. 596.—*Phil. Trans.* 1793, 1800.

not felt by the retina; too strong a light hurts it, and renders it unfit for action.

When the retina receives too strong a light, the impression is called *dazzling;* the retina is then incapable for some time of feeling the presence of the light. This happens when one looks at the sun. After having been long in the dark, even a very feeble light produces dazzling.—When the light is exceedingly weak, and the eye made to observe objects narrowly, the retina becomes fatigued, there follows a painful feeling in the orbit, and also in the head. Of dazzling.

A light, of which the intensity is not very strong, but which acts for a certain time upon a determined point of the retina, renders it at last insensible in this point. When we look for some time at a white spot upon a black ground, and afterwards carry the eye to a white ground, we seem to perceive a black spot; this happens because the retina has become insensible in the point which was formerly fatigued by the white light. In the same manner, after the retina has been some time without acting in one of its points, whilst the others have acted, the point which has been in repose becomes of an extreme sensibility, and on this account objects seem as if they were spotted. In this manner it is explained, why, after having looked a long time at a red spot, white bodies appear as if spotted with green; in this case, the retina has become insensible to the red rays, and we know that a ray of white light, from which the red is subtracted, produces the sensation of green. Of spots seen on Objects.

The same sort of phenomena happen when we have looked long at a red body, or one of any other colour, and afterwards look at white, or differently coloured bodies.—We perceive with facility the *direction* of the light received by the retina. We believe instinctively that light proceeds in a right line, and that this line is the prolongation of that according to which the light penetrated into the cornea. Therefore, whenever the light has been modified in its direction, before reaching the eye, the retina gives us nothing certain. Optical illusions proceed principally from this cause. The retina perceives the direction of the light.

The retina can receive at the same time impressions in every point of its extent, but the sensations which result from them are then incorrect. It may be affected by the image of one or two objects only, though a much greater number be impressed on it; the vision is then much more defined.

The central part of the retina the most sensible.

The central part of the membrane appears to possess much more sensibility than the rest of its extent; we therefore make the image fall on this part when we wish to examine an object with attention.

Does the light act upon the retina by simple contact only, or must it traverse this membrane? The presence of the choroid in the eye, or rather the dark matter which covers it, renders this second opinion the most probable.

That part of the retina which corresponds with the centre of the optic nerve, has been said to be insensible to the impression of light. I know nothing which can directly prove this assertion.*

* Were even the experiment of Mariotte, cited in all works on natural philosophy, correct, which, however, I much doubt, still it would be wrong to conclude that the retina is insensible at the point corresponding to the centre of the optic nerve. (38)

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(38) The experiment of Mariotte consists in placing two objects, as two candles, on the same level with the eye, and receding from them in a direction perpendicular to the line of junction, till one of them disappear. Its image is then upon the entrance of the optic nerve, as can be proved by measurement. "To discover the place of entrance of the optic nerve, I fix two candles at ten inches distance, retire 16 feet, and direct my eye four feet to the right or left of the middle space between them; *they are then lost in a confused spot of light:* but any inclination of the eye brings one or other of them into the field of view. From this experiment, the distance of the centre of the optic nerve from the visual axis is found to be 16–100 of an inch." See Young's Nat. Ph. II. 583. From the details of this experiment the student may easily renew it, in order to ascertain its correctness. Having repeatedly succeeded in the experiment myself, I entertain no doubt either of the fact or the explanation; and consider the reasoning of Le Cat, Mariotte, Euler, Clairault, &c., as perfectly legitimate in this respect, as far as regards the insensibility of the optic nerve. But Mariotte and his followers endeavoured to prove, that the retina had nothing to do with vision; that the entrance of the optic nerve was the point where the choroid was wanting, and the optic fibre the most abundant, and yet was the only spot of the posterior concave of the eye in which vision did not take place. Hence their obvious conclusion, that the choroid coat was the sole organ of vision—a fact, they said, which is proved incontestably by the continuity of the choroid and iris, and the fact that the contractions and dilatations of the latter are chiefly regulated by the impulse of light upon the posterior concave of the eye, which impulse is more likely to be conveyed to the iris through its own than a foreign texture. As the controversy receives a new interest from Dr. Knox's late discovery, the curious reader may find the substance of it in Haller's El. Phys. V. 471—480.

Action of the Optic Nerve.

There is no doubt that the optic nerve transmits to the brain, in an instant, the impression that the light makes on the retina; but by what mechanism we are entirely ignorant. The manner in which the two optic nerves are confounded upon the *sphenoïd bone*, ought, doubtless, to have a considerable influence upon the transmission of the impressions received by the eyes;—but this is also a point upon which it is difficult to form any probable conjecture. Action of the Optic Nerve.

Action of the Eyes.

Notwithstanding what has been said at different periods, as well as the late efforts of M. Gall, to prove that we see with only one eye at a time, there seems sufficient proof not only that the two eyes concur at the same time in the production of vision, but that it is absolutely necessary this should be so, for certain most important operations of this function. There are however certain cases in which it is more convenient to employ only one eye; for instance, when it is necessary to understand perfectly the *direction* of the light, or the *situation* of any body relative to us. Thus we shut one eye to take aim with a gun, or to place a number of bodies upon a level in a right line. Cases in which only one eye is employed.

Another case in which it is advantageous to employ only one eye is, when the two organs are unequal, either in refractive power or in sensibility. For the same reason we shut one eye when we employ a telescope. But, except in these particular cases, it is of the utmost importance to employ both eyes at once. I will here prove by an experiment which I have made myself that both eyes see the same object at the same time.

Receive the image of the sun upon a plane in a dark chamber; put before your eyes two thick glasses, each of which presents one of the prismatic colours. If your eyes are good, and both equally strong, the image of the sun will appear of a dirty white, whatever be the colour of the glasses employed. If one of your eyes is much stronger than the other, the image of the sun will be seen of the same colour as the glass which is before the strongest eye. These results have been proved before M. Tillaye, junior, in the physical chamber of the faculty of medicine.

One object produces then really two impressions whilst the brain perceives only one. To produce this the motions of the two eyes must be in unison. If, after a disease, the movement of the eyes are no longer regular, we receive two impressions from the same object, which constitutes *strabismus*, or squinting. We may also, at pleasure, receive two impressions from one body; for that purpose, it is only necessary to derange the harmony of the two eyes.

Estimation of the Distance of Objects.

Vision is produced essentially by the action of light upon the retina, and yet we always consider the bodies from which light proceeds as being the cause of it, though they are often placed at a considerable distance. This result can be produced only by an intellectual operation.

The manner in which we judge of the distances of objects.

We judge differently of the distances of bodies according to the degree of that distance; we judge correctly when they are near us, but it is not the same when they are at a short distance; our judgment is then often incorrect; but when they are at a great distance, we are constantly deceived. The united action of the two eyes is absolutely necessary to determine exactly the distance, as the following experiment proves.

Suspend a ring by a thread, and fix a hook to the end of a long rod, of a size that will easily pass the ring; stand at a convenient distance, and try to introduce the hook: in using both eyes, you may succeed with ease in every attempt you make; but if you shut one eye, and then endeavour to pass the hook through, you will not succeed any longer; the hook will go either too far or else not far enough, and it will only be after trying repeatedly that it will be got through. Those persons whose eyes are very unequal in their power, are sure to fail in this experiment, even when they use them both.

When a person loses an eye by accident, it is sometimes a whole year before he can judge correctly of the distance of a body placed near him.* Those who have only one eye, determine distance, for the most part, very incorrectly. (39) The size of the object, the intensity of

* I have seen a person who, in consequence of losing one eye, was for months afterwards obliged to grope after objects within his reach, before he could seize them.

(39) Many well-informed persons, reduced to the use of one eye, deny *in toto* the positions here advanced, and maintain that their judgment of the position, distance, or properties of bodies has undergone no change whatever by the loss of the other.

the light that proceeds from it, the presence of intermediate bodies, &c. have a great influence upon our just estimation of distance.

We judge most correctly of objects that are placed upon a level with our bodies. Thus, when we look from the top of a tower at the objects below, they appear much less than they would if they were placed at the same distance, on the same plane with ourselves. Hence the necessity of giving a considerable volume to objects that are intended to be placed on the tops of buildings, and which are to be seen from a distance. The smaller the dimensions of an object are, the nearer it ought to be to the eye, in order to be distinctly seen. What is called the distinct point of view, is also very variable. A horse is seen very distinctly at six yards, but a bird could not be distinctly seen at the same distance. If we wish to examine the hair or the feathers of those animals, the eye requires to be much nearer. However, the same object may be seen distinctly at different distances; for example, it is quite the same to many persons whether they place the book that they are reading at one or two feet of distance from the eye. The intensity of the light which illuminates an object, has a considerable effect upon the distance at which it can be distinctly seen.

Estimation of the Size of Bodies.

Manner in which we judge of the size of bodies.

The manner in which we arrive at a just determination of the size of bodies, depends more upon knowledge and habit than upon the action of the apparatus of vision. We form our judgment relative to the dimensions of bodies, from the size of the image which is formed in the eye, from the intensity of the light which proceeds from the object, from the distance at which we think it is placed, and, above all, from the habit of seeing such objects. We therefore judge with difficulty of the size of a body that we see for the first time, when we cannot appreciate the distance. A mountain which we see at a distance for the first time, appears generally much less than it really is; we think it is near us when it is very far away.

Beyond a distance somewhat considerable, we are so completely deceived, that judgment is unable to correct us. Objects appear to us infinitely less than they really are: as happens with the celestial bodies.

Estimation of the Motion of Bodies.

Estimation of the motion of bodies.

We judge of the motion of a body by that of its image upon the retina, by the variations of the size of this image, or, which is the same thing, by the change of the direction of the light which arrives at the eye.

In order that we may be able to follow the motion of a body, it ought not to be displaced too rapidly, for we could not then perceive it; this happens with bodies projected by the force of gunpowder, particularly when they pass near us. When they move at a distance from us, the light comes from them to the eye for a much longer space of time, because the field of view is much greater, and we can see them with more facility. We ought to be ourselves at rest, in order to judge correctly of the motions of bodies.

When bodies are at a considerable distance from us, we cannot easily perceive their motions to or from us. In this case, we judge of the motion of the body, only by the variation of the size of its image. Now this variation being infinitely small, because the body is at a great distance, it is very difficult, and frequently impossible, for us to estimate its motion. Generally we perceive with great difficulty, sometimes we cannot perceive at all, the motion of a body which moves extremely slow; this may be on account of the slowness of its own motion, as in the case of the hand of a watch, or it may be the result of the slow motion of the image, which happens with the stars, and objects very far from us.

Of Optical Illusions.

Of Optical Illusions.

After what we have just said, of the manner in which we estimate the distance, the size, and the motion of bodies, we may easily see that we are often deceived by sight. These deceptions are known in Physics, and in Physiology, by the name of optical illusions. Generally we judge pretty well of bodies placed near us; but we are most commonly deceived with regard to those that are distant. Those illusions which happen to us with regard to objects that are near us, are the result, sometimes of the reflection, sometimes of the refraction, of light before it reaches the eye; and sometimes of the law that we establish instinctively; namely, that light proceeds always in right lines.

We must refer to this cause those illusions occasioned by mirrors: objects are seen in plane mirrors at the same distance behind them, as the mirrors are distant from the eye. To this cause may be attributed also the apparent increase, or diminution of bodies seen through a glass. If the glass make the rays converge, the body will appear greater; if it cause them to diverge, the body will appear less. These glasses produce still another illusion; objects appear surrounded by the colours of the solar spectrum, because their surfaces not being parallel, they decompose light in the manner of the prism.

We are constantly deceived by objects at a distance, in a manner that we cannot prevent, because those deceptions result from certain laws which govern the animal economy. An object seems near us in proportion as its image occupies a greater space upon the retina; or in proportion to the intensity of the light which proceeds from it.

Of two objects of a different volume, equally illuminated and placed at the same distance, the greatest will appear the nearest, should circumstances be such as to admit of the distance being justly estimated. Of two objects of equal volume, placed at an equal distance from the eye, but unequally illuminated, the brightest will appear the nearest; it would be the same, if the objects were at unequal distances, as can be easily seen in looking at a string of lamps: if there happen to be one of them brighter than the rest, it will appear the nearest, whilst that which is really the nearest will appear the farthest, if it is the least bright. An object seen without any intermedium, always appears nearer than when there happens to be between it and the eye, some body that may have an influence upon the estimation that we make of its distance.

When a bright object strikes the eye, whilst all the objects around it are obscured, it appears much nearer than it really is; a light in the night produces this effect.

Objects appear always small in proportion as they are distant: thus, the trees in a long alley, appear so much smaller, and so much nearer together, in proportion as they are farther from us. It is by observing these illusions, and the laws of the animal economy, upon which they are founded, that art has been enabled to imitate them. The art of painting, in certain cases, merely transfers to the canvas, those optical errors into which we most habitually fall. (40)

The construction of optical instruments, is also founded upon these principles: some of them augment the intensity of the light, which proceeds from the objects observed; others cause it to diverge, or converge, in order to increase or diminish their apparent volume, &c.

By the constant exercise of the sense of sight, we are enabled to get over many optical illusions, as will be proved by the curious history of the blind youth, spoken of by Cheselden.

History of the Blind Lad related by Cheselden.

This celebrated English surgeon, by a surgical operation,* procured sight to a very intelligent person who was born blind: and he observed the manner in which this sense was developed in this young man. "When he saw the light for the first time, he knew so little how to judge of distances, that he believed the objects which he saw touched his eyes, (and this was his expression) as the things which he felt touched his skin. The objects which were most pleasant to him were those whose form was regular and smooth, though he had no idea of their form, nor could he tell why they pleased him better than the others. During the time of his blindness he had such an imperfect idea of colours, that he was then able to distinguish, by a very strong light, that they had not left an impression sufficient by which he could again recognise

* Generally said to be that for cataract, but, more probably, it was a division of the *membrana pupillaris*.

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(40) This fact is familiar to artists, though little observed by authors. It is at the same time proved and illustrated, by comparing a good landscape painting with the image of the same in a mirror, or the *camera obscura*.—The latter appears just perspective, but a bad representation. Our illusions constitute a necessary and pleasing part of vision; the camera obscura gives us but the skeleton, the shadow as it were, of the object, not the copy of our impressions. The same deception obtains in poetry and fiction. We yawn over the dry, exact anatomy of the passions, as portrayed by Cowley and his imitators; we detest the ghastly dissections of Godwin and Maturin; while the soft delusive sketches of Moore,—even the masculine but equally false caricatures of Byron,—the soothing unction to human vanity, and prejudice, which issues quarterly from the pen of our great fabulist, afford us a never failing source of wonder and delight. In all these instances it is the imagination, rather than real existence, which is represented; and our pleasure arises, not from the renewed memory of the thing, but of the idea of it previously existing in the mind, which is merely a compound of prejudice, error, and illusion, founded on fact.

them. Indeed when he saw them he said the colours he then saw were not the same as those he had seen formerly; he did not know the form of any object; nor could he distinguish one object from another, however different their figure or size might be: when objects were shown to him which he had known formerly by the touch, he looked at them with attention, and observed them carefully in order to know them again; but as he had too many objects to retain at once, he forgot the greater part of them, and when he first learned, as he said, to see and to know objects, he forgot a thousand for one that he recollected. It was two months before he discovered that pictures represent solid bodies; until that time he had considered them as planes and surfaces differently coloured, and diversified by a variety of shades; but when he began to conceive that these pictures represented solid bodies, in touching the canvas of a picture with his hand he expected to find in reality something solid upon it, and he was much astonished when, upon touching those parts which seemed round and unequal, he found them flat, and smooth like the rest; he asked, which was the sense that deceived him,—the sight or the touch? There was shown to him a little portrait of his father, which was in the case of his mother's watch; he said, that he knew very well it was the resemblance of his father; but he asked, with great astonishment, how it was possible for so large a visage to be kept in so small a space, as that appeared to him as impossible as that a bushel should be contained in a pint. He could not support much light at first, and every object seemed very large to him; but after he had seen larger things he considered the first smaller: he thought there was nothing beyond the limits of his sight. The same operation was performed on the other eye about a year after the first, and it succeeded equally well. At first he saw objects with his second eye much larger than with the other, but not so large, however, 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 it appeared twice as large as with the first eye; but he did not see double, at least it could not be ascertained that he saw objects double, after he had got the sight of the second eye."

This observation is not singular; there exists a number of others, and they have all given results nearly alike.

The conclusion that may be drawn from it is, I think, that the exact manner in which we determine the distance, size, and form of objects, is the result of habit, or, which is the same thing, of the education of the sense of sight: this will be proved by the consideration of vision in different ages.

Vision in the different Ages.

Modification of Vision by the different Ages.

The eye is very early formed in the fœtus.

In the embryo, the eyes appear in the form of two little black points. At the age of seven months, they are capable of modifying the light, so as to form an image on the retina, as we have ascertained by experiment. Before this period, the eyes could not be of such use, since the pupil is shut by the pupillary membrane.* At seven months this membrane disappears: it is generally said that it breaks; probably it is absorbed. This is also the period of the *Viabilité*, or confirmed vitality of the fœtus. Fœtuses have been found, however, at six, and even at five months, the eyes of which presented no trace of this membrane.

The eye of a child, and that of an adult, are not quite the same: but their difference is not remarkable. In the first, the sclerotic is thinner, and even slightly transparent; the choroid is reddish on the outside, and the dark shade of the internal face is less deep; the retina has a greater proportional development; the aqueous humour is more abundant, which gives a greater projection to the cornea; the crystalline has also much less consistence than in the adult. The eyes are, before birth, closed, and, as it were, fixed together. In certain animals, they are joined by the *palpebral conjunctiva*, which passes from the one to the other, and which does not break until after birth.

From youth to manhood the quantity of the humours of the eye diminish insensibly; they afterwards diminish in a more evident degree: This diminution is more particularly manifest in old age.

* According to M. Edwards, the pupillary membrane is formed by the prolongation of the membrane of the aqueous humour, and of the external layer of the choroïd. He denies that any water is found in the anterior chamber before the rupture of this membrane; and proves that, previously, it is all accumulated in the posterior chamber; 1st, because the membrane so named is not its secretory organ; 2d, because it exists in the posterior chamber; 3d, because, before the seventh month, the same membrane of the aqueous humour is a shut sac, presenting all the characters of a serous membrane.

The crystalline, in particular, not only becomes more dense, but it takes a yellow colour, which is at first clear, and afterwards becomes more deep: whilst the crystalline suffers this change, it becomes harder, contracts a slight opacity, which increases with the progress of age, until it becomes completely opaque.

The eye is then well fitted in the new-born infant to act upon the light; there are also images formed upon the retina, as experience shows. In the first month of its life, however, the child gives no indication of its being sensible to the light; its eyes move only slowly, and are very unsteady; it is only towards the seventh week that it begins to give proofs of sensibility. At first, only a very bright light is capable of engaging its attention; it seems to be pleased in looking at the sun; it becomes soon sensible to the ordinary light of day. It does not yet, however, distinguish any object; the first that attract its attention are those which are red; it is generally best pleased with lively colours. After some days, it looks steadfastly at bodies, the colours of which it seems to distinguish; but it has no idea either of size or distance. It stretches out its hand to seize objects, however distant; and as food is the most pressing of its wants, it carries every thing it seizes to its mouth, of whatever dimensions. Thus the sight is very imperfect in the early part of life; but, by habit, and, above all, by the continual correction of errors into which the child falls, the judgment improves, and the sight becomes perfect by a real process of education. Vision in the Infant.

It has been supposed that infants see things double; there is nothing to prove this assertion. It has also been said, but without any good reason, that the refractive parts being more abundant, they ought to see objects smaller than they are. Infants do not see things double.

The eye soon acquires all the perfection of which it is susceptible, and it does not undergo any more new modifications until the approach of old age. Then the change that we indicated in the humours of the eye, tends to render it less distinct; but what contributes most to weaken it, is the diminution of sensibility in the retina.

Three causes unite to impair the sight in old age:— 1st, The diminution of the quantity of the humours of the eye, which diminishing the refractive power of the organ, prevents the old man from distinguishing with precision Vision in the Old.

surrounding objects; and in order to see them distinctly he is obliged to remove them to a distance, because the light which proceeds from them is then less divergent, or he is obliged to employ convex glasses, which diminish the divergence of the rays. 2d. The opacity beginning in the crystalline, which dims the sight, and tends by its increase to bring on blindness, in producing that malady known by the name of cataract. 3d. The diminution of the sensibility of the retina, or otherwise of the brain, which prevents the perceptions of impressions produced on the eye, and which leads to total and incurable blindness.

OF THE HEARING.

The hearing is a function intended to make known to us the vibratory motion of bodies.

Of Sound. Sound is to the hearing what light is to the sight. Sound is the result of an impression produced upon the ear by the vibratory motion impressed upon the atoms of the body by percussion, or any other cause. This word signifies also the vibratory motion itself. When the atoms of a body have been thus put in motion, they communicate it to the surrounding elastic bodies: these communicate it in the same manner, and so the vibratory motion is often continued to a great distance. In general, only elastic bodies are capable of producing and propagating sound; but for the most part solid bodies produce it, and the air is generally the medium by which it reaches the ear.

Intensity of Sound. There are three things distinguished in sound, *intensity*, *tone*, and *timbre* or *expression*. The intensity of sound depends on the extent of the vibrations.

Of Tone. The tone depends upon the number of vibrations which are produced in a given time, and, in this respect, sound is distinguished into *acute* and *grave*. The grave sound arises from a small number of vibrations, the acute from a great number.

Of distinguishable Sounds. The gravest sound which the ear is capable of perceiving, is formed of thirty-two vibrations in a second. The most acute sound is formed of twelve thousand vibrations in a second. Between these two limits are contained all the distinguishable sounds, that is, those sounds of which

Of Noises. the ear can count the vibrations. Noise differs from distinguishable sound in so much as the ear cannot distinguish the number of vibrations of which it is composed.

A distinguishable sound, composed of double the number of vibrations of another sound, is said to be its octave. (41) There are intermediate sounds, between these two, which are seven in number, and which constitute the *diatonic scale* or gamut; they are designated by the names, *ut, re, mi, fa, sol, la, si.*

Of fundamental and harmonic sounds.

When a sonorous body is put in motion by percussion, there is at first heard a sound very distinct, more or less intense, more or less accute, &c., according as it may happen; this is the fundamental sound: but with a little attention other sounds can be perceived. These are called harmonic sounds. This can be easily perceived in touching the string of an instrument.

The *timbre*, or expression of sound, depends on the nature of the sonorous body.

Sound is propagated through all elastic bodies. Its rapidity is variable according to the body which propagates it. The rapidity of sound in the air is a thousand and forty-two feet in a second—(1130 feet English.) (42) It is still more rapidly transmitted by water, stone, wood, &c. Sound loses its force in a direct proportion to the square of the distance; this happens at least in the air. It may also become more intense as it proceeds; as happens when it passes through very elastic bodies, such as metals, wood, condensed air, &c. All sorts of sounds are propagated with the same rapidity, without being confounded one with another.

It is generally supposed that sound is propagated in right lines, forming cones, analogous to those of light, with this essential difference, however, that, in sonorous cones, the atoms have only a motion of oscillation, whilst those of the cones of light have a real transitive motion.

Reflection of Sound.

When sound meets a body that prevents its passage, it is reflected in the same manner as light, its angle of re-

(41) See Dr. T. Young's "Essay on music," in Nat. Phil. II. 563.

(42) See also Young Nat. Phil. I. 370, who refers this measure to Derham; but Derham himself (*Physico-Theology*, p. 134) says, "that the *mean* of the flight of sounds is at the rate of a mile in nine half seconds and a quarter, or 1142 *feet in one second of time.* See Phil. Trans. II. 113." Mr. Goldingham (Annals of Phil., Sept. 1823) has confirmed this last measure by a number of decisive experiments performed at the observatory at Madras, which see.

flection being equal to the angle of incidence. The form of the body which reflects sound, has similar influence upon it. The slowness with which sound is propagated, produces certain phenomena, for which we can easily account. Such is the phenomenon of echo, of the mysterious chamber, &c.

Apparatus of Hearing.

Apparatus of Hearing.

The apparatus of hearing is very complex; we will not insist upon anatomical details, from which no advantage could arise; as the uses of the different parts that constitute this sense are but little understood.

In the same manner as in the apparatus of vision, there are in that of hearing a number of organs, which appear to concur in that function by their physical properties; and behind them, a nerve for the purpose of receiving and transmitting impressions.

The apparatus of hearing is composed of the outer, middle, and internal ear; and of the acoustic nerve.

External Ear.

This denomination comprehends the *Pinna*, and the *Meatus auditorius externus.*

Pavilion of the Ear.

The *Pinna* is of a greater or less size, according to the individual. Its external face, which, in a well formed ear, is a little anterior, presents five eminences, the *helix, antihelix, tragus, anti-tragus, lobula*; and three cavities, those of the *helix, fossa navicularis, concha.*

The Pinna is formed of a *fibrous cartilage*, elastic and pliant; the skin which covers it is thin and dry; adheres to the fibro-cartilage by a cellular tissue, which is compact, and contains very little adipose substance: the lobule alone contains it in considerable quantity. There are seen under the skin a number of sebaceous follicles, which furnish a micaceous white matter, that produces the polish and suppleness of the skin.

There are also seen, upon the different projections of the cartilaginous ear, certain muscular fibres, to which the name of *muscles* have been given, but which are only *vestigia.** The Pinna, receiving many vessels and nerves,

* Anatomists denominate *vestigia* those parts of animals which, in them, seem to serve no other purpose than to indicate the uniform plan which nature has followed in the construction of animals. (43)

(43) *Vestigium* is simply the *trace* of a structure more perfect in animals whose habits require its operation; but not developed in the instance spo-

is very sensible, and easily becomes red. It is fixed to the head by the cellular tissue, and by muscles, which are called, according to their position, *anterior*, *superior*, and *posterior*. These muscles are much developed in many animals: in man they may be considered as simple vestiges.

Meatus Auditorius.

This tube extends from the *concha* to the membrane of the *tympanum*; its length, variable according to age, is from ten to twelve lines in the adult; it is narrower in the middle than at the ends; it presents a slight curve above, and in front. Its external orifice is commonly covered with hairs, like the entrance to the other cavities. It is composed of an osseous part, of a fibro-cartilaginous substance, which is confounded with that of the pinna, of a fibrous part, which completes it above. The skin sinks into it, becoming thinner, and terminates in covering the external surface of the membrane of the *tympanum*. Below this skin exist a great number of sebaceous follicles, which furnish the *cerumen*, a yellow, bitter matter, the uses of which we shall afterwards describe. Meatus auditorius externus.

Middle Ear.

The middle ear comprehends the cavity of the tympanum, the little bones which are contained in this cavity, the mastoid cells, the Eustachian Tube, &c. Middle Ear.

The tympanum is a cavity which separates the external from the internal ear. Its form is that of a portion of a cylinder, but a little irregular. Its external partition presents, on the upper part, the *fenestra ovalis*, which communicates with the vestibule, and which is formed by a membrane; immediately below, a projection which is called *Promontory*; below this projection, a little groove, which lodges a small nerve; still lower, an opening called the *fenestra rotunda*, which corresponds to the external winding of the cochlea: and which is also shut by a membrane. The external side presents the *membrana Tympani*. This membrane is directed obliquely downward and inward; it is tense, very slender and transparent, Tympanum.

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ken of, because not necessary to the exercise of its functions. Thus the horse has something like a thumb, and man the vestigia of a tail, in the *os coccygis*; but as neither of these organs are required by their respective possessors, their traces are not found developed.

covered on the outside by a continuation of the skin, on the inside by the narrow membrane which covers the Tympanum; it is also covered on this side by the nerve called *Chorda Tympani:* its centre serves as a point of fixation for the extremity of the handle of the malleus; its circumference is fixed to the bony extremity of the meatus auditorius: it adheres equally in every point, and presents no opening that might admit a communication between the external and internal ear. Its tissue is dry, brittle, and has nothing analogous in the animal economy; there are neither fibres, vessels, nor nerves, found in it. The circumference of the tympanum presents, in the fore part, 1st, the opening of the Eustachian Tube, by which the cavity communicates with the superior part of the pharynx; 2d, the opening by which the tendon of the internal muscle of the malleus enters. Behind are seen, 1st, the opening of the mastoid cells,—irregular winding cavities, which are formed in the mastoid process, and which are always filled with air; 2d, the pyramid, a little hollow projection, which lodges the muscle of the *stapes;* 3d, the opening by which the *Chorda Tympani* enters into the hollow of the tympanum. Below, the tympanum presents a slit, called *glenoïd*, by which the tendon of the anterior muscle of the *malleus* enters, and the *Chorda Tympani* passes out, and goes to unite itself with the lingual nerve of the fifth pair.

Above, the circumference presents only a few small openings, by which blood-vessels pass. The cavity of the tympanum, and all the canals which end there, are covered with a very slender mucous membrane: this cavity, which is always full of air, contains, besides, four small bones, (the *malleus, incus, os orbiculare,* and *stapes*) which form a chain from the membrana tympani to the fenestra ovalis, where the base of the stapes is fixed. There are some little muscles for the purpose of moving this osseous chain, of stretching and slackening the membranes to which they are attached: thus, the internal muscle of the malleus draws it forward, bends the chain in this direction, and stretches the membranes; the anterior muscle produces the contrary effect: it is also supposed that the small muscle which is placed in the pyramid, and which is attached to the neck of the *stapes,* may give a slight tension to the chain, in drawing it towards itself.

Internal Ear, or Labyrinth.

This is composed of the *cochlea*, of the *semicircular canals*, and of the *vestibule*. Internal Ear.

The cochlea is a bony cavity, in form of a spiral, from which it has taken its name. This cavity is divided into two others, called the *gyri* of the cochlea, and which are distinguished into external and internal. The partition which separates them is a plate set edgeways, and which in its whole length is partly bony, and partly membranous. The external gyration communicates by the fenestra rotunda with the cavity of the tympanum; the internal gyration ends in the vestibule. Cochlea.

Semicircular Canals.

This name is given to three cylindrical cavities, bent in a semicircular form, two of which are disposed horizontally, and the others vertically. These canals terminate by their extremities in the vestibule. They contain bodies of a grey colour, the extremities of which are terminated by swellings. Semicircular Canals.

Vestibule.

This is the central cavity, the point of union of all the others. It communicates with the tympanum by the fenestra ovalis, with the internal gyration of the cochlea, with the semicircular canals, and with the internal meatus auditorius, by a great number of little openings. Vestibule.

The whole of the cavities of the internal ear are hollowed out of the hardest part of the petrous portion of the temporal bone: They are covered with an extremely thin membrane, and are full of a very thin and limpid fluid, called *Liquor of Cotunnius*, which can flow out by two narrow apertures, known by the name of the *aqueducts of the cochlea, and of the vestibule:* they contain, besides, the acoustic nerve.

Of the Acoustic Nerve.

This nerve proceeds from the fourth ventricle; it enters into the labyrinth by the holes that the internal auditory meatus presents in its bottom. Having entered into the vestibule, it separates itself into a number of branches, one of which remains in the vestibule, another enters into the cochlea, and two go to the semicircular canals. Scarpa has described the distribution of these different branches Acoustic Nerve.

in the cavities of the internal ear, and therefore it would be superfluous here to insist on details.

In terminating this short description, we remark that the internal and middle ear are traversed by several nervous threads, the presence of which is, perhaps, useful to hearing: It is known that the facial nerve proceeds a considerable space in a canal of the petrous portion. In this canal it receives a small thread of the vidian nerve; it furnishes the chorda tympani, which attaches itself to this membrane. There are two other nervous inosculations in the ear; to one of which M. Ribes called the attention of anatomists not long since; the other was recently discovered by M. Jacobson.

MECHANISM OF HEARING.

Uses of the Pinna.

Uses of the Pavilion.

The auricle collects the sonorous radiations, and directs them towards the meatus externus; in proportion as it is large, elastic, prominent from the head, and directed forward. Boerhaave supposed he had proved by calculation, that all the sonorous radiations (or pulsations) which fall upon the external face of the pinna, are, ultimately, directed to the auditory passage. This assertion is evidently erroneous, at least for those pinnae in which the *antihelix* is more projecting than the *helix*. How could those rays arrive at the concha, which fall upon the posterior surface of the antihelix? The pinna is not indispensable to the hearing; for, both in men and in the animals, it may be removed without any inconvenience beyond a few days.

The Pinna not indispensable.

Uses of the Meatus Auditorius.

Uses of the meatus auditorius externus.

This tube transmits the sound in the same manner as any other conduit, partly by the air it contains, and partly by its parietes, until it arrives at the membrane of the tympanum. The hairs, and the cerumen with which it is provided at the entrance, are intended to prevent the introduction of sand, dust, insects, &c.

Uses of the Membrane of the Tympanum.

Uses of the Membrane of the Tympanum.

This membrane receives the sound which has been transmitted by the meatus auditorius. In what circumstances is it stretched by the internal muscle of the malleus? Or when is it relaxed by the contraction of the anterior muscle of the malleus?—All our knowledge on this subject is merely conjectural. An opening made in this membrane does not much impair the faculty of hearing.* As this membrane is dry, and elastic, it ought to transmit the sound very well, both to the air contained in the tympanum, and to the chain of little bones. The chorda tympani cannot fail to participate in the vibrations of the membrane, and transmit impressions to the brain. The contact of any foreign body upon the membrane is very painful, and a violent noise also gives great pain. The membrane of the tympanum may be torn, or even totally destroyed, without deranging the hearing in any sensible degree.

Uses of the Cavity of the Tympanum.

Uses of the Cavity and of the little bones.

The uses of this are to transmit the sounds from the external to the internal ear. This transmission of sound by the tympanum happens—1st, by the chain of bones which has a particular action upon the membrane of the *fenestra ovalis*;† 2d, by the air which fills it, and which acts upon the whole petrous portion, but particularly upon the membrane of the *fenestra ovalis*; 3d, by its sides.

Uses of the Eustachian Tube.

Uses of the Tube.

The use of this part is to renew the air in the tympanum; its obliteration is said to cause deafness.

The notion of its being capable of carrying sounds to the internal ear is erroneous; there is nothing to support this assertion: it permits the air to pass in cases when the *tympanum* is struck by violent sounds, and it permits the renewal of that which fills the *tympanum*, and the mastoid cells. The air in the *tympanum* being much rarefied, is very suitable for diminishing the intensity of the sounds it transmits.

Uses of the Mastoid Cells.

Uses of the Mastoid Cells.

The use of the mastoid cells is not well known; it is supposed that they help to augment the intensity of the

* For the different opinions regarding the use of this membrane, vide Haller, p. 198, 199.

† The utility of the motion impressed upon this chain of bones is entirely unknown. The loss of none of them, except the stapes, destroys hearing; though we think we have observed, that persons so mutilated do not retain it above two or three years.

sound that arises in the cavity. If they produce this effect it ought to be rather from the vibrations of the partitions which separate the cells than from the air which they contain. Sound may arrive in the *tympanum* by another way than the external meatus; the shocks received by the bones of the head are directed towards the temples, and perceived by the ear. It is well known that the movement of a watch is heard distinctly when it is placed in contact with the teeth.

Uses of the internal Ear.

Uses of the Internal Ear.

We know little of the functions of the internal ear; we can only imagine that the sonorous vibrations are propagated in different modes, but principally by the membrane of the *fenestra ovalis*, by that of the *fenestra rotunda*, and by the internal partition of the *tympanum;* that the liquor of Cotunnius ought to suffer vibrations which are transmitted to the acoustic nerve. It may be conceived how necessary it is that this liquid should give way to those vibrations which are too intense, and which might injure this nerve: Possibly, in this case, it flows into the aqueducts of the *cochlea*, and of the *vestibule*, which, in this respect, would have a great deal of analogy with the *Eustachian tube*.

The internal *gyri* of the *cochlea* ought to receive the vibrations principally by the membrane of the *fenestra ovalis;* the vestibule, by the chain of bones; the semicircular canals, by the sides of the *tympanum*, and perhaps by the mastoid cells, which frequently extend beyond the canals. But the aid which is given to the hearing by each separate part of the internal ear is totally unknown.

The osseo-membranous partition, which separates the *cochlea* into two parts, has given rise to a hypothesis which no one now admits.

Action of the Acoustic Nerve.

Action of the Acoustic Nerve.

The impressions are received and transmitted to the brain by the acoustic nerve; the brain perceives them with more or less facility and exactness in different individuals. Many people have a false ear, which means that they do not distinguish sounds perfectly.

There is no explanation given of the action of the acoustic nerve and of the brain in hearing; but we have made some observations with regard to them.

In order to be heard, sounds must be within certain limits of intensity. Too strong a sound hurts us, whilst one too weak produces no sensation. We can perceive a great number of sounds at once. Sounds, particularly appreciable sounds, combined, and succeeding each other in a certain manner are a source of agreeable sensations. It is in such combinations, for the production of this effect that music is employed. On the contrary, certain combinations of sound produce a disagreeable impression; the ear is hurt by very acute sounds. Sounds which are very intense, and very grave, hurt excessively the membrane of the *tympanum*. By the absence of the liquor of *Cotunnius* the hearing is destroyed. When a sound has been of long duration, we still think we hear it, though it may have been some time discontinued.

Action of the two Apparatus.

We receive two impressions, though we perceive only one. It has been said that we use only one ear at once, but this notion is erroneous. Action of the Two Apparatus.

When the sound comes more directly to the one ear, it is, in reality, distinguished with more facility by that one, than by the other: therefore in this case we employ only one ear; and when we listen with attention to a sound which we do not hear exactly, we place ourselves so that the rays may enter directly into the concha; but when it is necessary to determine the direction of the sound, that is, the point whence it proceeds, we are obliged to employ both ears, for it is only by comparing the intensity of the two impressions, that we are capable of deciding from whence the sound proceeds. Should we shut one ear perfectly close, and cause a slight noise to be made, in a dark place, at a short distance, it would be utterly impossible to determine its direction; in using both ears this could be determined. In these cases the eye is of great use, for even in using both ears it is frequently impossible to tell in the dark from whence a sound comes. By the sound we may also estimate the distance of the body from which it proceeds; but in order to judge exactly in this respect we ought to be perfectly acquainted with the nature of the sound, for without this condition the estimation is always erroneous. The principle upon which we judge is, that an *intense sound proceeds from a body which is near*, whilst a *feeble sound proceeds from a body at a dis-*

Manner of estimating distances.

Manner of estimating the distances of sonorous bodies.

tance: if it happen that an intense sound comes from a distant body, whilst a feeble sound proceeds from a body which is near, we fall into acoustic errors. We are generally very subject to deception with regard to the point whence a sound comes; sight and reason are of great use in assisting our judgment.

The different degree of convergence, and divergence, of the sonorous rays, do not seem to have any influence on the hearing; neither are they modified in their course, except for the purpose of making them enter into the ear in greater quantity: it is to produce this effect that speaking trumpets are used for those who do not hear well. Sometimes it is necessary to diminish the intensity of sounds; in this case a soft and scarcely elastic body is placed in the external meatus.

Modifications of the Hearing by Age.

Hearing at Birth.

The ear is formed in the fœtus very early. Every thing that belongs to the internal ear, and to the small bones, is nearly the same at birth as afterwards; but the other parts of the middle and external ear are not yet capable of acting, which establishes a great difference between the eye and the ear. The *pinna* is relatively very small; it is soft, therefore inelastic, and very unfit to perform the functions which belong to it. The sides of the *meatus externus* partake of the structure of the *pinna;* the membrane of the *tympanum* is very oblique, and, in a certain degree, becomes a continuation of the superior side of the *meatus;* it is therefore very ill disposed to receive the sonorous vibrations. All the external ear is covered with a white soft matter, which also prevents it from fulfilling its functions.

The cavity of the *tympanum* is, in proportion, a little smaller; in place of air, it contains a thick mucus.

The mastoid cells do not exist at all. In the progress of age, the auditory apparatus acquires very soon in the adult the dispositions which we have indicated. In old age, the physical changes that it suffers, so far from being unfavourable, like the eye, seem on the contrary to give it a greater perfection; all the parts become harder and more elastic; the mastoid cells extending quite to the top of the petrous portion, thus surround all the cavities of the internal ear.

The loudest noises do not affect in any sensible degree the new-born infant; after some time it appears to notice acute sounds: these are also the sort of sounds that nurses employ to attract its attention. Hearing in the Infant.

It is very long before an infant can judge accurately of the intensity, and of the direction of sound, particularly before it comprehends the meaning of different articulate sounds. For a long time it pays most attention to the sounds which are acute and intense, in the same manner as it seems most delighted with a very brilliant light.

Though the auditory apparatus become more perfect, in a physical sense, with age, it is, however, certain that the hearing becomes more dull in the beginning of old age, and there are few old men who are not more or less deaf. This circumstance seems to be, on the one hand, from a diminution of the humours of Cotunnius, and on the other from a diminution of sensibility in the acoustic nerve. Hearing in the Aged.

THE SMELL.

There escapes from almost every body in nature certain particles of an extreme tenuity, which are carried by the air often to a great distance. These particles constitute odours; there is one sense destined to perceive and appreciate them: thus an important relation between animals and bodies is established. Of Odours.

All bodies of which the atoms are fixed are called inodorous.

The difference of bodies is very great relative to the manner in which odours are developed: some permit them to escape only when they are heated; others only when rubbed. Some again produce very weak odours, whilst others produce only those which are highly powerful. Such is the extreme tenuity of odoriferous particles, that a body may produce them for a very long time without losing weight in any sensible degree. Manner in which Odours are developed.

Every odoriferous body has an odour peculiar to itself.

As these bodies are very numerous there have been attempts made to class them, which have nevertheless all failed.

Odours can be distinguished only into weak and strong, agreeable and disagreeable. We can recognise odours Classification of Odours.

which are musky, aromatic, fetid, rancid, spermatic, pungent, muriatic, &c. Some are fugitive, others tenacious. In most cases an odour cannot be distinguished but by comparing it with some known body. There have been attributed to odours properties which are nourishing, medical, and even venomous; but in the cases which have given rise to these opinions, might not the influence of odours have been confounded with the effects of absorption? A man who pounds jalap for some time will be purged in the same manner as if he had actually swallowed part of it. This ought not to be attributed to the effects of odours, but rather to the particles which, being spread around, float in the air, and are introduced either with the saliva or with the breath: we ought to attribute to the same cause the drunkenness of persons who are exposed for some time to the vapours of spirituous liquors. The air is the only vehicle of odours; it transports them to a distance; they are also produced, however, *in vacuo*, and there are bodies which project odoriferous particles with a certain force. This matter has not yet been carefully studied; it is not known if, in the propagation of odours, there be any thing analogous to the divergence, the convergence, to the reflection, or the refraction of the rays of light. Odours mix, or combine, with many liquids, as well as solids. This is the means employed to fix, or preserve them. Liquids, gases, vapours, as well as many solid bodies reduced to powder, possess the property of acting on the organs of smell.

Propagation of Odours.

Apparatus of Smell.

Apparatus of Smell.

The olfactory apparatus ought to be represented as a sort of sieve, placed in the passage of the air, as it is introduced into the chest, and intended to stop every foreign body that may be mixed with the air, particularly the odours.

This apparatus is extremely simple; it differs essentially from that of the sight, and the hearing; since it presents no parts anterior to the nerve, destined for the physical modification of the external impulse, the nerve is to a certain degree exposed. The apparatus is composed of the pituitary membrane, which covers the nasal cavities, of the membrane which covers the *sinuses*, and of the olfactory nerve.

The pituitary membrane covers the whole extent of the nostrils, increases the thickness of the spongy bones very much, is continued beyond their edges and their extremities, so that the air cannot traverse the nostrils but in a long narrow direction. This membrane is thick, and adheres strongly to the bones and cartilages that it covers. Its surface presents an infinity of small projections, which have been considered by some as nervous *papillae*, by others as mucous follicles, but which, according to all appearance, are vascular. Pituitary Membrane

These small projections give to the membrane an appearance of velvet. The pituitary is agreeable and soft to the touch, and it receives a great number of vessels and nerves. The passages through which the air proceeds to arrive at the *fauces* deserve attention.

These are three in number; they are distinguished in anatomy by the names of inferior, middle, and superior *meatus*. The inferior is the broadest and the longest, the least oblique and least crooked; the middle one is the narrowest, almost as long, but of greater extent from top to bottom: the superior is much shorter, more oblique and narrower. It is necessary to add to these the interval, which is very narrow, and which separates the partition of the external side of the nostrils in its whole extent. These canals are so narrow that the least swelling of the pituitary renders the passage of the air in the nostrils difficult, and sometimes impossible. Direction of the air in traversing the Nostrils.

The two superior *meatus* communicate with certain cavities, of dimensions more or less considerable, which are hollowed out of the bones of the head, and are called *sinuses*. These *sinuses* are the *maxillary*, the *palatine*, the *sphenoidal*, the *frontal;* and those which are hollowed out of the *ethmoid bone*, better known by the name of ethmoidal cells. Of the Sinus.

The *sinuses* communicate only with the two superior *meatus*.

The *frontal*, the *maxillary sinus*, the anterior cells of the *ethmoid bone*, open into the middle *meatus;* the *sphenoidal*, the *palatine sinus*, the posterior cells of the *ethmoid*, open into the superior *meatus*. The *sinuses* are covered by other soft membranes, very little adherent to the sides, and which appear to be of the mucous kind. It secretes more or less abundantly a matter called *nasal mucus*, which is continually spread over the pituitary, and seems Of the Nasal Mucus.

very useful in smelling. A more considerable extent of the *sinus* appears to coincide with a greater perfection of the smell: this is at least one of the most positive results of comparative physiology.

Olfactory Nerve.

The olfactory nerve springs, by three distinct roots, from the posterior, inferior, and internal parts of the anterior lobe of the brain. Prismatic at first, it proceeds towards the perforated plate of the *ethmoid bone;* it swells all at once, and then divides itself into a great number of small threads, which spread themselves upon the *pituitary* membrane, principally on the superior part of it.

It is important to remark, that the filaments of the olfactory nerves have never been traced upon the inferior *spongy bones,* upon the internal surface of the middle (*meatus*), nor in any of the *sinuses.* The *pituitary* membrane receives not only the nerves of the first pair, but also a great number of threads, which spring from the internal aspect of the *spheno-palatine ganglion;* these threads are distributed in the *meatus,* and in the inferior part of the membrane. It covers also, for a considerable length, the ethmoidal thread of the nasal nerve, and receives from it a considerable number of filaments. The membrane which covers the sinus receives also a number of nervous ramifications.

The *nasal fossae* communicate outwardly by means of the nostrils, the form and size of which are very variable. The nostrils are covered with hair on the inside, and are capable of being increased in size by muscular action.—The nasal fossae open into the *pharynx* by the posterior nostrils.

Mechanism of Smelling.

Mechanism of Smell.

Smell is exerted essentially at the moment when the air traverses the nasal fossae in proceeding towards the lungs. We very rarely perceive any odour when the air proceeds from the lungs; it happens sometimes, however, particularly in organic diseases of the lungs.

The mechanism of smell is extremely simple:—It is only necessary that the odoriferous particles should be stopt upon the pituitary membrane, particularly in the places where it receives the threads of the olfactory nerves.

As it is exactly in the superior part of the nasal fossae, where the passages are so narrow, that they are covered with mucus, it is also natural that the particles should stop there.

We may conceive the utility of mucus: its physical properties are such that it appears to have a much greater affinity with the odoriferous particles than with air; it is also extremely important to the olfactory sense, that the *nasal mucus* should always preserve the same physical properties; whenever they are changed, as it is observed in different degrees of *coryza*, the smell is either not exerted at all, or in a very imperfect manner.

After what has been said of the distribution of the olfactory nerves, it is evident that the odours that reach the upper part of the nasal cavities will be perceived with greater facility and acuteness: for this reason, when we wish to feel more acutely, and with greater exactness, the odour of any body, we modify the air in such a manner that it may be directed towards this point. For the same reason, those who take snuff endeavour, also, to make it reach the upper part of the nasal fossae. The internal face of the *ossa spongiosa* appears well disposed to stop the odours at the instant the air passes. And, as there is an extreme sensibility in this point, we are inclined to believe that here the smell is exerted, though the filaments of the first pair have not been traced so far.

Physiologists have not yet determined the use of the external nose in smelling; it appears intended to direct the air charged with odours towards the superior part of the *nasal cavities.*

Those persons who have their noses deformed; particularly if broken—those who have small nostrils, directed forward, have in general almost no smell: the loss of the nose, either by sickness or accident, causes, almost entirely, the loss of smell. According to the interesting remark of M. Beclard, such people recover the benefit of this sense by the use of an artificial nose.

Use of the Sinuses.

What is the use of the *Sinuses?* The only use which is generally admitted, is that of furnishing the greater part of the nasal mucus. The other uses which are attributed to them are, to serve as a depot to the air charged with odoriferous particles, to augment the extent of the surface which is sensible to odours, and to receive a portion of the air that we inspire for the purpose of putting the power of smell in action, &c.—These are far from being certain.

Action of vapours and gases upon the pituitary membrane.

Vapours and gases appear to act in the same manner upon the pituitary membrane as odours. The mechanism of it ought, however, to be a little different. Bodies reduced to a coarse powder have a very strong action on this membrane, even their first contact is painful; but habit changes the pain into pleasure, as is seen in the case of taking snuff. In medicine, this property of the pituitary membrane is employed for the purpose of exciting a sharp instantaneous pain.

In the history of smell, the use of those hairs with which the nostrils and the nasal fossae are provided, must not be forgotten; (44) perhaps they are intended to prevent the entrance of foreign bodies along with the air into the nasal fossae. In this case, they would bear a strong analogy to the eye-lashes, and the hairs with which the ear is provided.

It is generally agreed that the olfactory nerve is especially employed in transmitting to the brain the impressions produced by odoriferous bodies; but there is nothing to prove that the other nerves, which are placed upon the *pituitary*, as well as those near it, may not concur in the same function.

Modifications of Smell by Age.

Modification of the Smell by age.

The olfactory apparatus is but little developed at birth; the nasal cavities, the different convoluted bodies, scarcely exist; the sinus do not exist at all, and yet the faculty of smelling appears to take place. I think I have observed children, a short time after birth, exercise the faculty of smell upon the food which was given them. The nasal cavities are developed with the progress of age, the sinus are formed, and it appears that, in this respect, the olfactory apparatus improves even to old age.

The smell continues to the last moments of life, certain injuries of the apparatus excepted, such as modifications in the secretion of the mucus, which happen very often.

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(44) These hairs are denominated *vibrissae* by anatomists. After the age of thirty, they begin to assume the colour and rigidity of the mustaches, and frequently require to be removed as regularly as the beard. Not to remove it was a mark of rusticity among the ancients;

> " Sed caput intactum buxo naresque pilosas
> " Annotet."—*Juv.* XIV. 194.

The smell is intended to inform with regard to the composition of bodies, and particularly of those used for food. Uses of Smell.

Commonly, a body whose odour is disagreeable is of little value for food, and frequently it is dangerous. Many animals appear to possess a much more delicate smell than we. This sense is, in other respects, a source of numerous sensations extremely agreeable, and which have a noted influence on the state of the mind.

TASTE.

Savours are only the impression of certain bodies upon the organ of taste. Bodies which produce it are called *sapid*.

It has been supposed that the degree of sapidity of a body could be determined by that of its solubility; but certain bodies, which are insoluble, have a very strong taste, whilst other bodies very soluble have scarcely any. The sapidity appears to bear relation to the chemical nature of bodies, and to the peculiar efforts which they produce upon the animal economy. The sapidity of bodies not in proportion to their solubility.

Tastes are very numerous, and very variable. There have been numerous endeavours made to class them, though without complete success; they are better understood, however, than the odours, no doubt owing to the impressions received by the sense of taste, being less fugitive than those received by the smell. Thus we are sufficiently understood, when we speak of a body having a taste that is *bitter*, *acid*, *sour*, *sweet*, &c. Classification of tastes.

There is a distinction of tastes which is sufficiently established, it being founded on the organization: that of agreeable and disagreeable. Animals establish it instinctively. This is the most important distinction; for those things which have an agreeable taste are generally useful for nutrition, while those whose savour is disagreeable are, for the most part, hurtful.

Apparatus of Taste.

The tongue is the principal organ of taste; however, the lips, the internal surface of the cheeks, the palate, the teeth, the *velum pendulum palati*, the *pharynx*, *œsophagus*, and even the stomach, are susceptible of receiving impressions by the contact of sapid bodies.

The salivary glands, of which the *excretory ducts* open into the mouth; the follicles which pour into it the *mucus*, which they secrete, have a powerful effect in forming the taste. Independently of the mucous follicles that the superior surface of the tongue presents, and which form upon it *fungous papillae*, there are also little inequalities seen, one sort of which, very numerous, are called *villous papillae;* the others less numerous, and disposed in two rows on the sides of the tongue, are called *conical papillae*.

Nerves of Taste.

All the nerves with which those parts are provided that are intended to receive the impressions of sapid bodies may be considered as belonging to the apparatus of taste. Thus the inferior maxillary nerves, many branches of the superior, amongst which it is necessary to notice the threads which proceed from the *spheno-palatine* ganglion, particularly the *naso-palatine* nerve of Scarpa, the nerve of the ninth pair, *glosso-pharyngeus*, appear to be employed in the exercise of taste.

The Nerves cannot be followed to the papillæ of the tongue.

The lingual nerve of the fifth pair is that which anatomists consider the principal nerve of taste; and as a reason they say that its threads are continued into the *villous* and *conical papillae* of the tongue. I have endeavoured, but in vain, to follow them so far; I have used the most delicate instruments, lenses and microscopes made on the principles of Dr. Wollaston, and all to no effect; they entirely disappear at the exterior membrane of the tongue. The other nerves of this organ present an equal difficulty. (45)

Mechanism of Taste.

Conditions which favour or injure the taste.

For the full exercise of taste, the mucous membrane which covers the organs of it must be perfectly uninjured; it must be covered with *mucous fluid*, and the saliva must

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(45) On this point, however, our author's testimony must only be allowed a negative value. Haller and Meckel both positively state, that they have traced the filaments of the gustatory nerve into the papillae of the tongue. Higher anatomical authority than their's can hardly be required; but M. Magendie's want of success certainly proves that the thing is difficult. *Vide Haller*, IV. 219, V. 104—112; *Meckel de Quinto pari*, 97; *Monro, Nervous System, Tab.* XXVI.

flow freely in the mouth. When the mouth becomes dry the powers of taste cannot be excited.

It is also necessary that these liquids undergo no change: for if the mucus become thick, yellow, and the saliva acid, bitter, &c., the taste will be exerted but very imperfectly.

Some authors have assured us that the *papillae* of the tongue become really erect during the time that the taste is exerted. This assertion I believe to be entirely without foundation.

It is quite enough that a body be in contact with the organs of taste, for us to appreciate its savour immediately; but if it is solid, in most cases it is necessary to dissolve in the saliva to be tasted; this condition is not necessary for liquids and gases.

Chymical actions of sapid bodies upon the Organs of Taste.

There appears to be a certain chymical action of sapid bodies upon the epidermis of the mucous membrane of the mouth; it is seen evidently at least in some, as vinegar, the mineral acids, a great number of salts, &c. In these different cases the colour of the epidermis is changed, and becomes white, yellow, &c. By the same causes, like effects are produced upon dead bodies. Perhaps to this sort of combination may be attributed the different kinds of impressions made by sapid bodies, as well as the variable duration of those impressions.

Hitherto no one has accounted for the faculty possessed by the teeth of being strongly influenced by certain sapid bodies. According to the researches of M. Miel, a distinguished dentist of Paris, this effect ought to be attributed to imbibition. The researches of M. Miel prove that the teeth imbibe very quickly liquids with which they are placed in contact. Different parts of the mouth appear to possess different degrees of sensibility for sapid bodies; for they act sometimes on the tongue, on the gums, on the teeth; at other times they have an exclusive action on the palate, on the pharynx, &c. Some bodies leave their taste a long time in the mouth; these are particularly the aromatic bodies. This *after-taste* is sometimes felt in the whole mouth, sometimes only in one part of it. Bitter bodies, for example, leave an impression in the pharynx; acids upon the lips and teeth: peppermint leaves an impression which exists both in the mouth and pharynx.

Duration of impressions.

Tastes, to be completely known, ought to remain some time in the mouth; when they traverse it rapidly, they leave scarcely any impression; for this reason we swallow quickly those bodies which are disagreeable to us; on the contrary, we allow those that have an agreeable savour to remain a long time in the mouth.

When we taste a body which has a very strong and pertinacious taste, such as a vegetable acid, we become insensible to others which are feeble. This observation has been found valuable in medicine, in administering disagreeable drugs to the sick. We are capable of distinguishing a number of tastes at the same time, as also their different degrees of intensity; this is used by chemists, tasters of wine, &c. By this means we arrive sometimes at a tolerably exact knowledge of the chemical nature of bodies; but such delicacy of taste is not acquired until after long practice.

Is the lingual nerve that which is essential to taste?—I know nothing which can make us attribute this property entirely to it. The experiment of M. Richerand does not appear to me to clear up this question; this learned professor is also of the same opinion.

Modifications of the Taste by age.

Taste in the fœtus, and child.

It is difficult to say if taste exists in the fœtus; the principal organ is very much developed, as well as the nerves that are employed in it. This sense exists in the new-born infant, as may easily be proved by putting a salt or bitter substance upon the tongue or in the mouth.—Children appear to have a very quick taste; they refuse, in general, all sorts of food which have a strong *goût*.

Of taste in old age.

Taste continues to extreme old age; it becomes weak indeed, and old people require food and drink which have a strong taste; but this is in unison with the wants of organization, to which active excitants are necessary for the preservation of its expiring powers.

Uses of taste.

The choice of food depends entirely on the taste; joined to smell, it enables us to distinguish between substances that are hurtful and those that are useful. It is this sense which gives us the most correct knowledge of the composition of chemical bodies.

OF TOUCH.

By touch we are enabled to know the properties of bodies; and as it is less subject to deception than the other senses, enabling us in certain cases to clear up errors into which the others have led us, it has been considered the first, and the most excellent of all the senses; but we will see that those advantages which have been attributed to it by physiologists and metaphysicians must be considerably limited.

We ought to distinguish *Tact* from touch. *Tact* is, with some few exceptions, generally diffused through all our organs, and particularly over the cutaneous and mucous surfaces. It exists in all animals: whilst touch is exerted evidently only by parts that are intended particularly for this use; it does not exist in all animals, and it is nothing else but *tact* united to muscular contractions directed by the will. Distinction of Tact and Touch.

In the exercise of *tact*, we may be considered as passive, whilst we are essentially active in the exercise of *touch*.

Physical Properties of Bodies which employ the Action of Touch.

Almost all the physical properties of bodies are susceptible of acting upon the organs of touch; form, dimensions, different degrees of consistence, weight, temperature, locomotion, vibration, &c. are all so many circumstances that are exactly appreciated by the touch. Physical properties of Bodies that act upon the Organs of Touch.

The organs destined to touch do not alone exercise this function; so that in this respect the touch differs much from the other senses. As in most cases it is the skin which receives the tactile impressions produced by the bodies which surround us, it is necessary to say something of its structure. Apparatus of Touch.

The skin forms the envelope of the body; it is lost in the mucous membranes at the entrance of all the cavities; but it is improper to say that these membranes are a continuation of it.

The skin is formed principally by the *cutis vera*, or *chorion*, a fibrous layer of various thickness, according to the part which it covers; it adheres by a cellular tissue, more or less firm, at other times by fibrous attachments. The *chorion* is almost always separated from the subja- Of the Chorion.

cent parts by a layer of a greater or less thickness, which is of use in the exercise of touch.

Of the Epidermis.

The external side of the *chorion* is covered by the epidermis, a solid matter secreted by the skin. We ought not to consider the epidermis as a membrane; it is a homogeneous layer, adherent by its internal face to the *chorion*, and full of a great number of holes, of which the one sort are for the passage of the hair, and the other for that of cutaneous perspiration; they serve at the same time for the absorption which takes place by the skin. These last are called the pores of the skin.

Of the Pores of the Skin.

It is necessary to notice, with regard to the epidermis, that it is void of feeling: that it possesses none of the properties of life; that it is not subject to putrefaction; that it wears and is renewed continually; that its thickness augments or lessens as it may be necessary: it is even said to be proof to the action of the digestive organs.

Mucous body of Malpighi.

The connection of the epidermis to the chorion is very close; and yet it cannot be doubted that there is a particular layer between these two parts, in which certain particular phenomena take place. The organization of this layer is yet little known. Malpighi believed it to be formed of a particular mucus, the existence of which has been long admitted, and which bore the name of the corpus mucosum of Malpighi. Other authors have considered it, more justly, as a vascular network;* M. Gall makes it similar to the grey matter which is seen in many parts of the brain.

Vascular Buds of the Skin.

M. Gautier, in examining attentively the external surface of the true skin, has noticed some small redish projections, disposed in pairs; they are easily perceived when the chorion is laid bare by a blister. These little bodies are regularly disposed upon the palm of the hand, and on the sole of the foot. They are sensible, and are reproduced when they have been torn out. They appear to be essentially vascular. These bodies, without being understood, have been long called the *papillae* of the skin. The epidermis is pierced by little holes, opposite their tops, through which small drops of sweat are seen to issue, when the skin is exposed to an elevated temperature. The skin contains a great number of sebaceous follicles; it re-

* There are seen upon dead bodies, on the external surface of the *cutis vera*, numerous blood vessels, very delicate, and full of blood; and in the places where blisters have been applied some time before death.

ceives a great number of vessels and nerves, particularly at the points where the sense of touch is more immediately exercised.—The mode in which the nerves are terminated in the skin is totally unknown; all that has been said of the cutaneous nervous papillae is entirely hypothetical.

There exist no nervous papillae of the Skin.

The exercise of tact and of touch is facilitated by the thinness of the *cutis vera*, by a gentle elevation of temperature, by an abundant cutaneous perspiration, as well as by a certain thickness and flexibility of the epidermis; when the contrary dispositions exist, the tact and the touch are always more or less imperfect.

Conditions favourable to the exercise of Tact and Touch.

Mechanism of Tact.

The mechanism of tact is extremely simple; it is sufficient that bodies be in contact with the skin to furnish us with *data*, more or less exact, of their tactile properties. By tact we judge particularly of the temperature. When bodies deprive us of caloric, we call them cold: when they yield it to us, we say they are hot; and according to the quantity of caloric which they give or take, we determine their different degrees of heat or cold. The notions that we have of temperature are, nevertheless, far from being exactly in relation to the quantity of caloric that bodies yield to us, or take from us; we join with it unawares a comparison with the temperature of the atmosphere, in such a manner that a body colder than ours, but hotter than the atmosphere, appears hot, though it really deprive us of caloric when we touch it. On this account, places which have a uniform temperature, such as cellars, or wells, appear cold in summer, and hot in winter. The capacity also of bodies for caloric has a great influence upon us with regard to temperature; as an example of this we have only to notice the great difference of sensation produced by iron and wood, though the temperature of both be the same. (46)

Errors of the Tact.

(46) The heat of the skin being about 99°F., if there were no process employed to conserve this temperature, an atmosphere any thing below this point ought to communicate the sensation of diminished heat, or of cold. But the body is, in reality, furnished with a conservative process of this kind, and so powerful, that till the atmosphere sink below 62°F., the sensation of cold, or abstracted caloric, is not felt. This point, then, is the medium between *hot* and *cold*, in respect of the atmospheric air; but it varies a little according to the conducting power of the substance in contact.

A body which is sufficiently hot to cause a chemical decomposition of our organs produces the sensation of burning. A body whose temperature is so low as to absorb quickly a great portion of the caloric of any part, produces a sensation of the same sort nearly: this may be proved in touching frozen mercury.

The bodies which have a chemical action upon the epidermis, those that dissolve it, as the caustic alkalies, and concentrated acids, produce an impression which is easy to be recognised, and by which these bodies may be known.

Different points of skin have not the same sensibility.

Every part of the skin is not endowed with the same sensibility; so that the same body applied to different points of the skin in succession, will produce a series of different impressions.

Tact of the mucous Membranes.

The mucous membranes possess great delicacy of tact. Every one knows the great sensibility of the lips, the tongue, of the conjunctiva, the pituitary membrane, of the mucous membrane, of the *trachea*, of the urethra, of the vagina, &c. The first contact of bodies, which are not destined naturally to touch these membranes, is painful at first, but this soon wears off.

Mechanism of Touch.

Of the Hand.

In man the hand is the principal organ of touch; all the most suitable circumstances are united in it. The epidermis is thin, smooth, flexible; the cutaneous perspiration abundant, as well as the oily secretion. The vascular eminences are more numerous there than any where else. The chorion has but little thickness; it receives a great number of vessels and nerves; it adheres to the subjacent *aponeuroses* by fibrous adhesions; and it is sustained by a highly elastic cellular tissue. The extremities of the fingers possess all these properties in the highest degree: the motions of the hand are very numerous, and performed with facility, and it may be applied with ease to any body of whatsoever form.

As long as the hand remains immovable at the surface of a body, it acts only as an organ of *tact*. To exercise

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Thus, a bath at 62°. feels abundantly cold. Yet the range of variety from this cause is not great, probably because the sensibility to *hot* or *cold* is most acute about the limit of junction: for water becomes again tepid at 65°., and other bodies at still lower degrees, which have not, however, been well ascertained.—*See Cullen's First Lines*, § 89.

touch, it must move, either by passing over the surface, to examine form, dimensions, &c., or to press it for the purpose of determining its consistence, elasticity, &c.

We use the whole hand to touch a body of considerable dimensions; if, on the contrary, a body is very small, we employ only the points of the fingers. This delicacy of touch in the fingers has given man a great advantage over the animals. His touch is so delicate that it has been considered the source of his intelligence.

Perfection of touch in man.

From the highest antiquity the touch has been considered of more importance than any of the other senses; it has been supposed the cause of human reason. This idea has continued to our times; it has been even remarkably extended in the writings of Condillac, of Buffon, and other modern Physiologists. Buffon, in particular, gave such an importance to the touch, that he thought one man had little more ability than another, but only in so far as he had been in the habit of making use of his hands. He said it would be well to allow children the free use of their hands from the moment of their birth.

Touch has no prerogative over the other senses.

The touch does not really possess any prerogative over the other senses; and if in certain cases it assists the eye or the ear, it receives aid from them in others, and there is no reason to believe that it excites ideas in the brain of a higher order than those which are produced by the action of the other senses.

Modifications of Tact and Touch by age.

Does the fœtus possess *tact* and touch? Probably it does not, at least in taking it in the most limited sense. It is supposed that the first contact of the air upon the skin of a new-born infant occasions acute pain, and is the cause of its crying. I conceive that this idea is not well founded. (47)

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(47) The contact of air upon the skin of the new-born child is also supposed to be the cause of the commencement of the process of respiration at that time, by its impulse on the nerves of the face being communicated to the lungs, through the connections of the 5th, 7th, and great Sympathetic nerves, with the eighth or Pneumogastric nerve. The notion is not at all tenable, but we have not room for the arguments employed in its defence here. The reader will find both in Haller's Physiology, VIII. 397.

Touch in old people.

Both *tact* and touch lose much of their delicacy by age. They become sensibly impaired in the aged; but this is occasioned by the skin undergoing an unfavourable change: the epidermis is no longer so flexible, and the perspiration by the skin becomes imperfect; and the fat which formerly sustained the *chorion* having disappeared, it becomes wrinkled and flaccid. It may be easily understood that all these causes injure the exercise both of *tact* and touch; above all, when it is known that the entire faculty of perception is much diminished in old people.

The touch is capable of arriving at a great degree of perfection, as is seen in many professions. For medical men a very delicate sense of touch is absolutely necessary.

Of Internal Sensations.

All the organs, as well as the skin, possess the faculty of transmitting impressions to the brain, when they are touched by exterior bodies, or when they are compressed, bruised, &c. It may be said that they generally possess *tact*. There must be an exception made of the bones, the tendons, the *aponeuroses*, the ligaments, &c.; which in a healthy state are insensible, and may be cut, burned, torn, without anything being felt by the brain.

The bones, ligaments, &c. are insensible in a healthy state.

This important fact was not known to the ancients; they considered all the white parts as nervous, and attributed to them all those properties which we now know belong only to the nerves. These useful results, which have had a great influence upon the recent progress of surgery, we owe to Haller and his disciples.

All the organs are capable of transmitting spontaneously a great number of impressions to the brain without the intervention of any external cause. They are of three sorts. The first kind take place when it is necessary for the organs to act; they are called *wants, instinctive desires*. Such are hunger, thirst, the necessity of making water, of respiration; the venereal impulse, &c. The second sort take place during the action of the organs; they are frequently obscure, sometimes very violent. The impressions which accompany the different excretions, as of the *semen*, the urine, are of this number.

Instinctive wants.

Sentiments which accompany the action of the organs.

Such are also the impressions which inform us of our motions, of the periods of digestion:—even thought seems to belong 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 is variable in the different sorts of functions. Feelings which follow the action of the organs.

The impressions which are felt in sickness ought to be added to these three sorts: these are much more numerous than the others. The study of them is absolutely necessary to the physician. Painful sensations.

All those sensations which proceed from within, and which have no dependence upon the action of exterior bodies, have been collectively denominated *internal sensations*, or *feelings*. They were neglected by the metaphysicians of the last age; but they have been studied in our times by many distinguished authors, particularly by Cabanis, and M. Destutt Tracy, and their history is one of the most curious parts of *Idéology*.

Of the pretended Sixth Sense. (48)

Buffon, in speaking of those vigorous, agreeable sensations which are produced by the connection of the sexes, says, in a figurative language, that they are dependent on a sixth sense.

The professors of magnetism, and particularly those of Germany, speak a great deal of a sense which is present in all the others, which wakes when they sleep, and which is displayed more especially in *sleep-walkers:* those persons receive from it the power of predicting events. Of the Sixth Sense.

The instinct of animals is formed by this sense; and it enables them to foresee dangers which are near. It resides in the bones, the bowels, the ganglion, and the plexus of the nerves. To answer such reveries would be a mere losing of time.

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(48) It is just possible that there may exist senses yet unknown to us, but they certainly have not hitherto been discovered. What is called instinct in infants, and in the animal creation, might with propriety be considered as a sixth sense; but it exerts itself in so many forms, and resembles so much, in many points, the influence of reason or habit, that it is wiser to remain contented with the original five, since they cannot be disputed. Every one has heard of the pretty paradox, which maintains that there exists only one sense: namely, that of *Touch*, into which all the others are capable of being resolved. Sight is the contact of light upon the Retina; hearing, the contact of the liquor of Cotunnius upon the Acoustic nerve; smell, of the odoriferous particles upon the Schneiderian membrane, &c., &c. This is evidently a mere form of speech, and requires no commentary.

A peculiar organ having been discovered by M. Jacobson in the *os incisivum* of animals, he supposed that it might be the source of a distinct order of sensations, but without producing any sort of proofs.

To conclude, the faculty possessed by bats, of flying in the darkest places, caused Spallanzani, and M. Jurine of Geneva, to imagine that they were endowed with a sixth sense; but M. Cuvier has shown that this faculty of guiding themselves in the dark ought to be attributed to the sense of touch.

There exists, then, no sixth sense.

OF SENSATIONS IN GENERAL.*

The sensations form the first part of relative life; they establish our passive relations with surrounding bodies and with ourselves. This expression of *passive*, as will be easily perceived, is true only in a certain respect; for the sensations, as well as the other functions, are the result of the action of the organs, and are therefore essentially active.

Causes which operate on the organs of sense.

Every thing that exists, is capable of acting on our senses; by this means alone we are informed of the existence of bodies. Bodies sometimes act directly upon our organs; sometimes their action takes place by the means of intermediate bodies, such as light, odours, &c.

Most bodies are capable of acting on several of our senses; others have no action but on one.

Apparatus of sensations.

The apparatus of the sensations, or the senses, is formed of an exterior part which presents physical properties in relation with those of bodies, and of nerves which receive the impressions and transmit them to the brain.

Exterior part.

The exterior apparatus of sight and of hearing is very complex; in the other senses it is very simple: but in the whole, the relation between their physical properties and substances is such, that the least alteration of these cause a marked confusion in the function.

* General considerations being founded on the knowledge of particular facts, we shall always place them after the latter: Such an order is conformable to the mechanism by which ideas are formed.

OF THE NERVES.

Of the Nerves.

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

Every nerve has two extremities: the one is confounded with the substance of the brain; the other is variously disposed in the organs. These two extremities have by turns been called the *origin* or *termination of the nerves*.

Extremities of the nerves.

Some suppose that the nerves spring from the brain, and terminate in the organs; others imagine that the nerves have their origin in the organs, and form the brain by their union. These expressions are not exact, and present a false idea; they could be useful only in the description of the organs; and as they can be easily replaced without confusion, perhaps it would be better to abandon them. It is clear that *the brain is no more formed by the union of the nerves,* than *that the nerves spring from the brain.* We express metaphorically by these terms, the site or disposition of the two extremities of every nerve.

Cerebral extremities of the nerves.

The cerebral extremity of the nerves presents very fine soft filaments, which become a continuation of the substance of the brain, at a little distance from the point where they begin to be seen. These filaments united form the nerve.

The nerves different from one another.

The nerves are in some respects very different from one another: some are round, others are flat; others seem to have their sides fluted; some are very long, others are very short. As to colour and form, there are not two nerves which are exactly alike. They are in general so placed as to be rarely exposed to external injuries.

Extremities or terminations of the nerves.

The nerves in their direction towards different parts are divided into different ramifications; they terminate in the organs in such fine filaments, that they can be no longer seen, even by optical instruments. The nerves communicate with each other, join and form what is called a *plexus*. Except the optic nerve, of which the organic extremity can easily be seen, and that of the ear, upon which we have some notions, the disposition of the extremities of the nervous filaments is totally unknown. There has been much said of the extremities, or nervous *papillae*, which are still spoken of in physiological explanations; but every thing which has been said on this subject is purely imaginary. It can easily be shown that the bodies that have been, and are still called nervous *papillae* are not so.

Structure of the nerves.

The nerves are generally formed of very fine filaments, which are probably divided into threads still finer, if our means of division were sufficiently perfect to discover them. These filaments, which have been called nervous fibres, communicate frequently with one another, and affect in the body of the nerves, a disposition which is the same on a small scale as the plexus is on a great. It is generally supposed that every fibre is formed by an envelope (*neurilema*), and a central pulp of the same nature as the cerebral substance. I believe what has been said in this respect, is merely hypothetical.

Nervous fibres.

I have endeavoured to repeat the preparations according to the directions of anatomists in order to see this structure, and whatever care I may have taken, I have never yet succeeded. The tenuity alone of the nervous fibres, seems to me a powerful objection. When, by the aid of the microscope, the fibre itself can scarcely be seen, and which may reasonably be supposed to be formed of a number of smaller fibres, how is it possible to distinguish a cavity filled with a pulp?

Chemical composition of the nerves.

Whatever is the physical disposition of the substance that forms the *parenchyma* of nervous fibres, it possesses exactly the same chemical properties as the cerebral substance, and every nerve receives numerous little arteries, in relation to its volume, and it presents venous radicles in the same proportion.

Ganglion.

The posterior branch of all the nerves that spring from the spinal marrow, has, not far from the point where it unites with the anterior branch, a swelling which is called *ganglion*. These bodies, of a colour, consistence, and structure, quite different from those of the nerves, have no use which is known. The nerve of the eighth pair, at the point where it passes out of the skull, presents very often a swelling of this kind.

Of the Mechanism, or Physiológical Explanations of the Sensations.

Action of the nerves in sensation.

The physiological explanations of sensation consist in applying more or less exactly the laws of physics and of chemistry to the physical properties presented by the part of the apparatus placed before the nerves, as might have been remarked above, in the particular history of each sensation. As soon as we arrive at the use of the nerves in these functions there is no longer any explanation: it is then necessary to pay attention only to the phenomena.

This consequence, very easy to be deduced, appears to have been felt only by a small number of authors, and it is expressed but vaguely in their works. There have been constantly endeavours made to explain this action of the nerves. These organs were considered as the conductors of the animal spirits by the ancients. When Physiology was governed by mechanical ideas, the nerves were considered as vibrating chords, without its ever being recollected that they possess none of the physical conditions necessary for vibration.

Some able men have supposed that the nerves were the conductors, and even the secreting organs of a subtile fluid, which they called *nervous:* according to them, the sensations are transmitted to the brain by means of this fluid. At present, whilst the imponderable fluids engross the attention of the learned, there are a considerable number of this opinion. I know some enlightened persons whose talents do honour to our age, and who are not far from the belief that electricity acts a considerable part in the sensations and in other functions. To give an explanation of the sensations by referring them to a vital property that is called the *animal, perceptive, relative, &c.* is having recourse to the worst mode of explanation: for the word that expresses the thing is simply changed, and the difficulty remains the same.

To avoid premature decision, we arrange the action of the nerves amongst the vital actions, which, as was shown in the beginning of this work, are not susceptible, in the present state of science, of any explanation. But is it very certain that the nerves are the agents of the transmission of impressions received by the senses? Observation and experience demonstrate this in a peremptory manner. (49)

Action of the nerves in sensation.

(49) The late Dr. Gordon was strongly inclined to answer in the negative the question here proposed by our author. His arguments were too numerous to be repeated in this place, but seemed chiefly to be drawn from extreme cases of individuals, living, and performing the most usual functions of life and sensation, after some considerable portion of the nervous system had been destroyed or removed, apparently of sufficient mag-

Should a person receive a wound which affects a nervous trunk, the part where this nerve spreads becomes insen-

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nitude to suspend all motion. Thus the famous case that occurred to Dessault, wherein, after the spinal marrow had been completely divided by a bullet, the person was able to walk about, and perform other motions of the lower extremities, &c., was with him a favourite and reiterated topic, though scarcely more than Haller's collection of instances of cerebral lesions, and the curious, still unexplained, examples of acephalous children, said to have been alive at birth. The Doctor, however, used always to conclude his eloquent defence of the non-agency of the nervous system in his lectures, by remarking, "that if it should after all prove inaccurate, it would at least have the merit of promoting investigation." Setting aside all partiality for this amiable preceptor, it really does appear doubtful whether the nerves are entitled to all that influence which is generally ascribed to them in health and disease: nay, whether even many intense sensations can properly be referred to them. Whole tribes of polypi and other *Mollusca*, seem to enjoy motion and sensation without the smallest vestige of nerves being discoverable in them; the heart, the most active organ of our system, is still reputed void of proper nerves by several anatomists. What nerve is it which perceives the horrible sensation that arises during suffocation? or that sense of sinking so familiar in diseases of the heart? or of vertigo, from slight derangements of the motion of the blood within the cranium? or of bland vegetable acid, in fine, applied to the enamel of the teeth? Without wishing to go so far as Dr. Gordon, or his precursor, Dr. Simpson of St. Andrews, we may surely be allowed to express ourselves on the office of the nerves, in more guarded terms than those admitted in the text. A case, still more interesting than that of Dessault, because thoroughly verified by the investigations of M. Magendie and others, has just been described in our Author's "*Journal de Physiologie*," for April, 1823. In it, "the lower and upper part of the spinal chord was almost completely separated from each other by an interval of six or seven inches; yet the will governed the motions of the limbs, and the imagination stimulated the genital organs!"

In the paragraph immediately above, our author introduced the subject of the nervous fluid; but, so long as the internal motions of fluids continue to be inexplicable by mechanical principles, it must be found difficult to explain, or even to conceive the effect of impulse on the nervous system, which is rather a fluid than a solid mass. Certainly the chief objection to the doctrine of vibrations has been drawn from the fluidity of the nervous pulp. That, however, this system acts by fits,—or, in other words, has intervals of rest interposed between its operations, seems proved by the sensation of tingling in a torpid limb, or in any part whose nerve has been so far pressed, as to render its action imperfect. This same rapid alternation of activity and rest in the nervous organs, is also the probable cause of those indefinitely minute, alternating, contractions and relaxations of a muscle, of which Dr. Wollaston, P. R. S., has shown each larger contraction to be composed. If the assertors of nervous vibration only understood by it this alternation of action and quiescence, it seems hard to deny them a generalization supported by so many phenomena. But it is to be feared that they have carried it farther than mere observation taught them; and, like the modern British champions of nervous electricity, have endeavoured, by every exertion of oratory and logic, to pass off a solitary, imperfectly understood fact, for a great general law of nature; thus, with reason and sible. If the optic nerve has suffered, the person becomes blind; he becomes deaf, if the acoustic nerve has been injured. These efforts may be produced at pleasure upon animals, either by cutting, or binding, or compressing the nerves. When the ligature or the pressure is removed from the nerve, the part then becomes sensible as before. The wounding of a nerve produces dreadful pain as well to man as to animals. Every species of disease which changes, even in a slight degree, the tissue of the nerves, has a manifest influence upon their function of transmission.

The nature of those numerous junctions which take place amongst them is completely unknown: the suppositions that have been made to explain their use show plainly that physiology is but yet in its cradle.

Augmentation of the vivacity of sensations.

Sensations are quick or feeble. The first time that a body acts on our senses, it produces generally a strong impression. If the action is repeated, the quickness of the impression diminishes; by constant repetition it may lose its effect almost entirely. This fact is expressed by saying that *habit blunts the feeling*. The intensity of existence being measured by the vivacity of the sensations, man constantly seeks new ones which are more vivid: thence arise his inconstancy, inquietude, and weariness, if he remain exposed to the same causes of sensations.

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explanation in their mouths, throwing clouds of deeper darkness over what was already abundantly obscure. It is proper, however, that the student know something of these opinions; he will find the arguments for them all in Haller's El. Phys. vol. iv.; not even excepting the modern theme of the agency of the electric fluid, which, however, he will meet more at length in the Physiological Lectures of Mr. Abernethy, and in "*The Vital Functions*" of *W. Philips*.

Their arguments in favour of the nerves being influenced by electricity, come all to four heads:—

1. Electricity is the most powerful stimulus of nerves.
2. Electricity maintains not only the nervous action, but other subordinate actions, as digestion, depending on them.—*See Philips' celebrated experiments on the section and galvanism of the eighth pair.*
3. Some animals, as the *Torpedo, Conger*, and many other aquatic animals, named electric, have the power of secreting or accumulating electricity within themselves, which is never exhausted without the nervous system of the animal becoming similarly exhausted.
4. The aptitude of this fluid to those rapid motions, of which we know that the nervous principle is capable.

It is but too evident that much must be added to these, before they can establish the point assumed by rigorous demonstration.

We are capable of rendering our sensations more vivid and exact. For this purpose we dispose the sensitive apparatus in the most suitable manner, we receive only a few sensations at a time, and we give our whole attention to them: thence arises a great difference between seeing and looking, hearing and listening. The same difference exists between the ordinary use of the smell and actual smelling, between the taste and tasting, touching and feeling.

We can diminish the vivacity of sensations.

Nature has also given us the faculty of diminishing the vivacity of sensations. Thus we draw together the eyebrows, and make the eye-lids come nearer together when the impression produced by the light is too strong; we breathe with the mouth when we wish to avoid too strong an odour.

Reciprocal influence of sensations.

The sensations assist, direct, modify, and are even capable of injuring mutually each other. The smell seems to be the guide and sentinel of taste; the taste, in its turn, exercises a powerful influence over the smell. The smell may separate its functions from those of the taste. What pleases the one does not always please the other: but as food and drink cannot pass through the mouth without acting more or less upon the nose, whenever they are disagreeable to the taste they soon become so to the smell, and those that were most disagreeable to the smell terminate by becoming inoffensive, when they are very agreeable to the taste.*

The loss of one sense renders the others more acute

Numerous observations prove that the vivacity of impressions received by the senses increases by the loss of one of these organs. As an example of this, blind and dumb people have the smell much more perfect than persons who possess all their senses. I think I have observed, however, that the absence of smell does not render the other senses more acute.

Sensations of pain and pleasure.

The sensations are agreeable or disagreeable: the first, particularly when they are vivid, constitute pleasure; the second constitute pain. By pain and pleasure, nature makes us concur in the order that she has established amongst organized beings.

Though it cannot be said, without a sophism, that pain is only a shade of pleasure, it is, nevertheless, certain that persons who have exhausted every source of enjoyment,

* Cabanis.

and are thus become insensible to all the ordinary causes of sensations, seek out causes of pain, and seem to enjoy their effects. Are there not, in all great cities, men who are so debauched, and degraded by licentiousness, that they endeavour to find agreeable sensations in situations that would produce to others the most intolerable pains?

It is proper to remark that the sensations which come from the senses are, in general, exact and distinct; our ideas, and all the knowledge which we have of nature, proceed more immediately from them. The ideas come from external sensations.

The sensations which proceed from within, or the feelings, do not present these characters. Generally they are vague, confused, and frequently we know not even what they are; they are always more or less fugitive, and do not become fixed in the mind.

If our organs act freely, and according to the ordinary laws of organization, the sensations which arise from it are agreeable, and this action may even give us the most vivid pleasure; but, if our functions are confused, if our organs are wounded or diseased, or if their action is prevented, the internal sensations are painful, and, according to the sort of prevention, or injury, they assume a particular character. For this reason pain ought to be an important consideration in the study of medicine.

Are those nerves which come directly to the brain, or to the spinal marrow, the organs of transmission of our internal sensations? This is probable; nevertheless, the physiologists of the present day seem to allow a great part of this use to what they call the great *sympathetic*.* Perhaps they may have guessed aright; but, at present, it is impossible to admit this opinion; it is founded on no fact, on no positive experiment. Nerves which transmit the sensations.

* Why consider the great sympathetic as a nerve? Its ganglions and filaments have no analogy with the nerves properly so called; their colour, form, consistence, disposition, tissue, chemical and structural properties, are totally different. The analogy is not better marked in regard to their vital properties; a ganglion is cut, or torn out, without the animal appearing at all conscious of the injury. I have often made those attempts on the cervical ganglia of dogs and horses: but similar operations on the cerebral nerves, would have produced the most dreadful torture. Should all the ganglions of the neck be removed, and even the first thoracic, yet no sensible derangement will follow, not even of the parts into which their filaments can be traced. For what reason, then, are we to consider the system of the ganglions as making a part of the nervous system? Would it not be wiser, and more conducive to the advancement of science, to confess, that at present the use of the sympathetic nerve is unknown?—The

Modifications of the sensations by age, sex, &c.

The causes which modify the external or internal sensations are innumerable; age, sex, temperament, the seasons, climate, habit, individual disposition, are all so many circumstances, which, separately, would be enough to occasion numerous modifications in the sensations: and on being united, it is reasonable to suppose that the result should be more manifest. The difference of the sensations of individuals is expressed in common language by this phrase: *every one has his own way, or his own feelings.*

Sensations in the fœtus.

Probably the fœtus has only internal sensations; this may be, at least, supposed by the movements which it performs, and which seem to result from impressions arising spontaneously in the organs. It is known by direct experiments, that derangements which happen in the circulation, or the respiration of the mother, are followed by very distinct movements in the fœtus.

Sensations at birth.

At birth, and sometime after, all the senses do not exist. The taste, the touch, the smell, are the only ones which are then in exercise; sight and the hearing are later in coming to perfection, as we have mentioned in the history of the functions.

Education of the senses.

Each sense ought to arrive by degrees at its state of perfection: it is, then, indispensable that each should be subjected to a real process of education. If the development of the senses in an infant be carefully followed, as has been done by some metaphysicians, we can easily ascertain the modifications which they undergo in coming to perfection.

The education is more difficult and slow for those sensations which are exercised at a distance; for those which are produced by contact it is much more rapid, and appears to be more easy. During the time that this education of the senses continues, that is, in early youth, the sensations are weak and confused; but those that succeed them, and particularly those of young people, are remarkable for their multiplicity and their vivacity. At this age they are deeply engraven in the memory, and are therefore destined to form a part of our intellectual existence during the remainder of life.

perusal of authors may well confirm this idea. Every one has his own doctrine. Sometimes the ganglia are considered as nervous centres, sometimes as little brains, nuclei of cineritious matter, destined to nourish the nerves, &c. If we ask the proof, it is mere assertion; and that assertion a *jeu d'esprit!*

The sensations lose their vivacity as age advances; but they improve in exactness, as is seen in the adult. In old people they become weak, and are produced slowly and with difficulty. This effect applies more to the senses by which we distinguish the physical properties of bodies, and much less to those by which we learn their chemical properties. These last senses, the *taste* and *smell*, alone preserve some activity in old age; the others are nearly extinct by the diminution of sensibility, and by the succession of physical changes that they have suffered. Sensations in old age.

Of the Functions of the Brain.

The intellect of man is composed of phenomena so different from every thing else in nature, that we refer them to a particular being which is considered as an emanation of the Divinity. Intellect.

The belief of this being affords too much consolation, for the physiologist to call in doubt its existence; but the severity of the language, or of the logic, which physiology now demands, obliges us to treat of human intellect as if it were produced by the action of an organ. Very celebrated men have fallen into serious errors by not keeping this course; in following it there is a considerable advantage in being able to preserve the same method of study, and to render easy, things which have been generally regarded as almost above the human capacity. Soul.

OF THE BRAIN.

The brain is the material organ of thought: this is proved by a number of *experiments* and facts. Under this denomination of *brain*, I comprehend three parts which are really distinct, though united in certain points. These parts are the *brain*, properly so called, the *cerebellum*, and the *spinal marrow*. In each of these divisions there are other parts easy to distinguish, and which have, in a certain degree, a separate existence: so that nothing is more complicated, or more difficult in anatomy, than the study of the organization of the brain. Nevertheless, on account Brain.

of the importance of this organ, and of its functions, anatomists and physicians have always been much engaged in its dissection. The result of this study is, that the anatomical history of the brain is one of the most perfect parts of anatomy. Recently this matter has been cleared up anew by the publication of the work of M. M. Gall and Spurzheim, and by the labours to which they have given rise.

Means of protection of the Brain.

The brain, however, being of a very delicate texture, and its functions being injured by the least physical derangement, nature has been extremely careful to defend it against every injury arising from surrounding bodies. Amongst the protecting parts of the brain, that might be called *tutamina cerebri*, we ought to notice the hair, the skin, the *epicranii* muscles, the *pericranium*, the bones of the skull, and the *dura mater*, which are particularly destined to defend the brain, and the *cerebellum*.

By their number, and the manner in which they are disposed, the hairs are very proper to deaden any strokes which may fall on the head, and to prevent strong pressure from wounding the skin. Being a bad conductor of caloric, they form a sort of *felt*, whose meshes intercept the air; so that they are very well suited to preserve a uniform temperature in the head, to a certain degree, independent of that of the air and the surrounding bodies; besides, being impregnated with an oily matter, the hair imbibes but a small quantity of water, and very soon dries.

Hair being a bad conductor of electricity, the head becomes, in a certain degree, isolated by it: whence it happens that the electric fluid has but little influence on the brain.

We may easily conceive how the skin of the head, the muscles that it covers, and the scalp, concur in the protection of the head: it is not necessary to insist on this point.

The Skull.

Of all the protections of the brain the most effective is that afforded by the bones of the skull. On account of the hardness of this covering, and its spheroidal form, all pressure, or percussion upon the head, is distributed from the point struck, or pressed, over all the others, and falls less upon the brain. Suppose a person receives a stroke on the top of the head: the motion is propagated in every direction, even to the middle of the base of the skull, that is, to the body of the *sphenoid* bone. If the stroke had been upon the brow, it would have been propagated and concentrated towards the middle of the *occipital* bone.

Of this transmission of motion communicated to the skull, it has been supposed, that a slight reciprocal displacement of the bones takes place, not observed on account of the structure of the different articulations; but there is every reason to believe that the skull resists as if it were formed of only one piece.*

One circumstance which has not been sufficiently insisted on is, that the skull must necessarily change its form every time that it is forcibly pressed, or struck. The peculiar softness of the cerebral mass enables it to support those slight changes of its envelope without any inconvenience. The brain, in proportion to its softness, will suffer percussions and pressures with less danger: and on this account, new-born children, whose bones are soft and moveable, may have their heads compressed, and even sensibly deformed, without any bad effect. The same thing happens with older children, to whom no danger results even from very severe blows on the head. In childhood, and particularly at birth, the brain is much softer than in the adult. (50) Change of form of the Skull.

The *dura-mater* is disposed to protect, in a certain degree, the brain against itself. Without those folds which it forms in the *falx cerebri*, the *tentorium*, and the *falx cerebelli*, the hemisphere of one side would press upon the Dura-mater.

* If the brain were perfectly fluid and homogeneous, no injurious effect could result from the most extensive change of shape in its envelope; but as the brain is of a soft consistence, not homogeneous in every point, it follows that blows not very forcible are often followed by serious accidents, as concussion, effusion, abscess, &c. &c.

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(50) The brain, in childhood, is almost fluid. It is said by Gordon, that, according to the Wenzels, it attains its full weight before the third, its full size before the seventh year: which, however, is not borne out by the part of their table which he quotes; according to it, the full weight of the brain not being attained before the *fifth* year. *Gord. Anat.* p. 172–3. Though even this is hard of belief, the reader must not confound the growth of the head with that of the brain within. The mean greatest length of the skull is $6\frac{59}{120}$, breadth, $5\frac{23}{120}$ inches; according to Dr. Monro's measurement of adults, *Outl.* I. 351. Hatters add the two diameters together, and take their arithmetical mean for the diameter of hats, which surround and measure the external, visible circumference of the head. As the number of heads they measure is immense, and they themselves are void of all theory, the following table, obtained from an eminent manufacturer, and exhibit-

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 reciprocally injure each other's action.

Were we to compare the precautions taken by nature to preserve the brain from external injuries, with those taken to preserve the spinal marrow, we would presume that this last is of greater importance than the other, or that its more delicate texture required greater care for its protection: this is what really exists. The spinal marrow is, at least, of as great importance in the animal economy, as the *cephalic* portion of the nervous system. The least shake, the least pressure, injures it, and destroys its functions: it was then necessary that the *vertebral canal* might afford it a powerful protection. This protection is, accordingly, so complete, that an injury of the spinal marrow is very rare. The vertebral column ought to unite in itself great solidity with great mobility; it is the general

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ing the mean diameters of the *external head* at the different ages, may assist us in comparing the growth of the brain with that of the head:

"TABLE OF MEAN DIAMETERS OF HEADS.

For a child of 1 year, - - -	$5\frac{5}{8}$ inches.	
———— 2 years, - - -	$5\frac{7}{8}$	
———— 4 years, - - -	$6\frac{1}{8}$	
———— 7 years, - - -	$6\frac{5}{8}$	; it then varies little till 12.
————12 years, - - -	$6\frac{3}{4}$	
————16 to 18 years, -	$6\frac{7}{8}$	
Adults, - - - - - - - - -	$7\frac{1}{6}$	; largest, $7\frac{3}{4}$ to $8\frac{3}{4}$ inches.

Servants' heads, generally small, $6\frac{3}{4}$ to $7\frac{1}{4}$: also negroes' heads are small. Women's heads are more roundish than men's, and nearly all of a size."

From this table, and Dr. Monro's taken in comparison, it appears that at 7 years the *head* has attained only the same size as the *brain* exhibits in adults. The brain, therefore, within the head ought at 7 years to have attained its full size. This is the age at which the frontal sinuses begin to enlarge, and they continue to add to the dimensions of the head till twenty-one; and though this separation of the external from the internal table of bone, appears subversive of phrenological theory, it does not all prove that no further, or other addition, is made to the size of the head during its progress. On the whole, however, the growth, even of the head after 7 years, is much less than could have been expected. The length of the brain proper, after the 7th year, is between 6 and 7 inches; its breadth from 5 to 6 inches, five lines, (English?) Of the cerebellum, in like manner, the length is 2 inches, and from 2 to 8 lines; breadth from 3 inches and 9 lines to 4 inches and 4 lines. *Gord. Anat.* i. 172.

support of every effort made by the body; it is the centre of the movements of the members; it performs, by itself, very extensive motions.

We cannot enter into the details of this wonderful mechanism: on this subject may be read the *Traité d'Anatomie descriptive, of Bichât*, tom. I. page 161.

Besides the different envelopes of the brain of which we have spoken, and the *dura-mater* which covers it in its whole extent, this substance is every where surrounded with a very fine serous membrane, the principal use of which is to form a thin fluid which lubricates the brain. The *arachnoid* penetrates into all the cavities of the brain; it even forms a perspiratory fluid. Arachnoid.

The manner in which the blood vessels come to, and quit the brain is very singular: we will treat of them in the article *circulation*. We will simply mention here, that the arteries, before entering into the cerebral substance, are reduced to capillary vessels; that the veins are disposed in the same manner before quitting it: and as these very fine vessels have numerous communications with each other, there results from these, upon the surface of the brain, a vascular net-work, erroneously called the membrane of the *pia-mater*.

This net-work penetrates into the cavities of the brain; it forms, in the ventricles, the *plexus choroides*, and the *tela choroidea*. Pia-mater.

We will not give here the anatomical description of the brain, but confine ourselves to some general reflections on the subject.

A. Almost all the authors who have given an anatomical description of the brain, have not been sufficiently rigid in the expressions which they have employed, and have had their minds prejudiced by some hypothetical notion. It is indispensable to the future progress of anatomy, and of physiology, to employ only precise terms, to quit metaphorical expressions as much as possible, and particularly to reject the supposition, that all nerves terminate, or unite, in a certain point of the brain; that the soul has its seat in a particular part of this organ; that the nervous fluid is secreted by one portion of the cerebral mass, whilst the remainder acts as a conductor to this fluid, &c. By not having followed this course, authors, who have described the brain, have presented false ideas, and expressed themselves obscurely. Remarks upon the Brain.

The Brain divided into three distinct parts.

B. We ought to understand by the term *brain*, the organ which fills the cavity of the skull, and that of the vertebral canal. To render the study of it more easy, anatomists have divided it into three parts; the *brain*, properly so called, the *cerebellum*, and the *spinal marrow*. This division is purely scholastic. These three parts form, in reality, but one organ. The spinal marrow is no more a prolongation of the brain, than the brain is an enlargement of the spinal marrow.

The grey matter does not produce the white.

C. To say that the grey matter of the brain produces the white matter, is a supposition which goes for nothing; as the grey matter no more produces the white than a muscle produces the tendon which terminates it; no more than the heart produces the *aorta*. The system of anatomy of Gall and Spurzheim is particularly faulty in this respect.

The Brain of man in greater quantity than that of the animals.

D. In man, of all the animals, the brain proper, is the most voluminous. The dimensions of this organ are proportioned to those of the head. In this respect there is a great difference in different individuals. The volume of the brain is, generally, in direct proportion to the capacity of the mind. We ought not to suppose, however, that every man having a large head is necessarily a person of superior intelligence, for there are many causes of an augmentation of the volume of the head beside the size of the brain; but it is rarely found that a man distinguished by his mental faculties has not a large head. The only way of estimating the volume of brain in a living person is to measure the dimensions of the skull: every other means, even that proposed by *Camper*, is uncertain.

Of the central anfractuosities and circumvolutions.

E. The brain of man is that which offers the most numerous *circumvolutions*, and the deepest *sinuosities*. The number, the volume, the disposition, of the circumvolutions are variable; in some brains they are very large; in others they are less and more numerous. They are differently disposed in every individual; those of the right side are not disposed like those of the left. It would be an interesting research to endeavour to discover if there exist any relation between the number of *circumvolutions* and the perfection, or imperfection, of the intellectual faculties—between the modifications of the mind and the individual disposition of the cerebral *circumvolutions*.

F. The volume and the weight of the *cerebellum* is different in different individuals, and particularly with regard to different ages. In the adult the *cerebellum* is equal in weight to about the eighth or ninth part of the brain; in the new-born infant it is not above the sixteenth or eighteenth of it. (51) There are no *convolutions* observed at the surface of the *cerebellum*, but only lamellae placed above it, and each separated by a small furrow. The number of these *lamellae* is variable in different individuals, as well as the manner in which they are placed. For this we might repeat the remark which we made above, in speaking of the cerebral *convolutions*. An Italian anatomist (Malacarne) says, he found only three hundred and twenty-four plates in the *cerebellum* of a mad person, whilst he has found in others more than eight hundred.

Weight of the cerebellum.

Number of lamellae in the cerebellum.

The substance of the brain is soft and pulpy; its form changes easily of itself; it is almost liquid in the fœtus; it is more firm in infancy, and still more in manhood. The different degrees of solidity also vary in different points of the organ, and in different individuals. The brain has a spermatic, insipid, odour, which is very tenacious, and which has continued many years in dried brains. —(Chaussier.)

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(51) The Wenzels, in their book *De Penitiori Cerebri Structura*, give a table of the above relations, from which the following extract was made by the late Dr. Gordon:—

Age.	Weight of whole Brain.	Weight of Brain proper.	Weight of Cerebellum.	Ratio of Brain proper to Cerebellum.
	Grains.	Grains.	Grains.	
Five months after conception, -	720	683	37	$18\frac{17}{37}$: 1
At birth, - - -	6,150	5,700	450	$12\frac{2}{3}$: 1
3d Year, - - -	15,240	13,380	1,860	$7\frac{6}{31}$: 1
5th do. - - -	20,250	17,760	2,490	$7\frac{11}{83}$: 1
25th do. - - -	22,200	19,500	2,700	$7\frac{6}{27}$: 1
46th do. - - -	20,490	18,060	2,430	$7\frac{35}{81}$: 1
81st do. - - -	23,970	21,210	2,760	$7\frac{63}{92}$: 1

From their investigation it appears that the human brain attains its maximum size before the third, and maximum weight before the seventh year. Consequently it must be increasing in density from the third to the seventh.

Two substances.

G. There are two substances distinguished in the brain: one grey, the other white. The white substance, which is still called medullary, forms the greater part of the organ, and fills, more especially, the interior part of it, which corresponds to the base of the skull. It is more solid than the grey part; it has a fibrous appearance; it forms a great part of the spinal marrow, but particularly the outer part of it.

The grey substance, called cineritious, cortical, forms a layer of a variable thickness on the outside of the brain and of the cerebellum; there is grey matter, however, found in their interior: sometimes it is covered by the white matter, sometimes it appears mixed with it, or they are placed upon each other in alternate layers. In judging by the colour there are a number of other substances which might be distinguished in the brain, for there are parts which are yellow, black, &c.*

When we examine the cerebral substance with a microscope, it appears to be formed of an immense number of globules of different sizes. They are said to be eight times less than those of the blood; in the medullary substance they are disposed in straight lines, and have the appearance of fibres; in the grey substance they appear confusedly placed on one another.

According to M. Vanquelin, there is no difference of composition in the different parts of the nervous system: the analysis of the brain, of the cerebellum, of the spinal marrow and the nerves, gives the same result. He found in them all the same matter, the composition of which is—

Chemical composition of the Brain.

Water,	80.00
White fatty matter,	4.53
Red fatty matter,	0.70
Osmazome,	1.12

* M. Soemmering distinguishes four substances in the brain; the white, the grey, the yellow, and the black. (52)

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(52) Dr. Gordon employed the Wernerian nomenclature to designate its colours. He divides brain into two principal suites, white and brown matter: but he subdivides each of these into various shades—the white into orange white, yellowish white, or wine yellow; the brown, into wood brown, and greyish brown. Thus, according to that anatomist, the crura cerebri are *orange white;* the corpora quadrigemina, *yellowish white;* the pineal gland is *wood brown;* and the commissura mollis, *greyish brown.—Gord. Anat.* 130—137.

Albumen,	- - - - - - - - - - -	7.00
Phosphorus,	- - - - - - - - - -	1.50
Sulphur and Salts, such as		
Phosphate of Potass,	- - - - -	} 5.15
——— of Lime,	- - - - - -	
——— of Magnesia,	- - - -	

The arteries of the brain are large. They are four in number (the two internal carotids and the two vertebrals;) the particular disposition which they affect will be explained in the article *Arterial Circulation.* We only mention here that they are placed principally in the inferior part of the organ; that, by the manner in which they join, they form a circle, and that they are reduced to capillary vessels before entering into the tissue of the brain.

Arteries of the Brain.

The brain is supposed to receive the eighth part of the blood which flows from the heart; but this estimate is merely an approximation, and the quantity of blood which flows to the brain varies according to numerous circumstances. We know, from dissections lately made, that the cerebral arteries are accompanied by filaments of the great sympathetic nerve. These filaments are easily traced upon the principal branches of the arteries. It is to be presumed that they accompany them to their last divisions; but we must not conclude from this circumstance, which is general for all the arteries, that the brain receives nerves. The filaments of the great sympathetic have, here, as elsewhere, a relation only to the tunics of the arteries.

The cerebral veins have also a particular disposition: they occupy the upper part of the organ; they present no valve; they terminate in canals situated between the plates of the *dura-mater, &c.* We will return to this point at the article *Venous Circulation.* There have not been any lymphatic vessels observed in the brain.

Veins of the Brain.

Observations made upon the Brain of Man, and upon that of Living Animals.

It has been remarked that, in new-born children, whose skulls are yet membraneous, and in adults whose brains have been laid bare by disease or wounds, the brain has two distinct species of motion. The first is evidently isochronous with the beating of the heart and the arteries; the second has an equal relation to respiration; that is, the organ seems to sink, and contract upon itself, the instant of inspiration, whilst it presents a contrary phenomenon during expiration. According as the movements of respiration are more or less forcible, those of the brain are more or less evident. These two sorts of movements can be seen with great facility in animals, and it is astonishing how they could have been lately called in question. It is thought that they are hardly perceptible when the skull is entire, and that they are necessary to the preservation of the cerebral functions; but there is nothing proved in this respect. (53)

Pressure of the Brain.

In the dead body the brain and the cerebellum fill exactly the cavity of the skull; consequently in life, when these parts receive a great quantity of blood, when their vessels are distended by this fluid, when a copious vapour is constantly formed, either on the surface, or in the ventricles, we imagine that the brain and the cerebellum must support a considerable pressure, the intensity of which ought to be variable according to the quantity of blood which enters or leaves the brain.

Pressure of the spinal marrow.

The spinal marrow does not fill exactly the cavity of the vertebral canal, nor can it suffer a pressure in the manner of the brain; but the *pia-mater* exerts a manifest pressure upon it, so that it is nearly in the same state as the brain in regard to pressure.

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(53) It will not detain the reader long to explain briefly the cause of these two motions. That which corresponds to the pulsation of the arteries, is simply the effect of the hard, unyielding nature of the bones which constitute the base of the cranium; they refuse to yield downwards to the lateral dilatation of the arteries, which is consequently exerted wholly in the perpendicular direction: producing a corresponding alternate motion, or pulsation, in the brain. Some curious investigations of this motion may be seen in Richerand's Physiology.

The second movement corresponds to those of respiration. While we expire, the lungs collapse, and, as has been long *known*, but lately demonstrated by Dr. Williams, of Liverpool (*Ed. Med. and Sur. Journal, Oct.* 1823; *Annals of Phil. Sept.* 1823), transmit less blood than usual to the pulmonary veins, so that these organs are then almost empty. Hence blood is accumulated successively in the right ventricle, right auricle, superior cava, and cerebral veins. Thus the quantity of blood in the cranium and brain is increased, and with it the volume of the brain, which rises gently up into larger dimensions, until the act of inspiration, by enlarging the cells of the lungs, permits the accumulated blood to descend and pass through the latter. In the meanwhile the brain descends, and in this manner, alternately, the rising and falling of the brain correspond to expiration and inspiration.—*See Hall. El. Phys.* iii. 344.

With respect to the two pulsations of the brain above mentioned, a very authentic case of it occurred to the celebrated Professor Blumenbach.—*Ell. Blum. Phys.* p. 133.

This pressure appears indispensable to the actions of the organ. Whenever it is augmented or diminished suddenly, the functions are suspended; if the diminution or augmentation proceeds slowly, the cerebral functions continue.

The uses of the brain in the animal economy are very numerous and important. It is the organ of intelligence; it furnishes the principle of our action upon exterior bodies; it exerts a greater or less influence upon all the phenomena of life; it establishes an active relation amongst the different organs, or it is the principal agent of *sympathies.* (54) We shall consider it here only in respect to the first.

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(54) Sympathy, or conjunct suffering, is when one organ is observed to suffer something, when another is affected. Thus the laughing movements of the head and trunk, usually produced by tickling the soles of the feet, is a good example of sympathy. If we can explain it by nerves in any way connecting the parts, we term it NERVOUS SYMPATHY, otherwise we generally denominate it *contiguous* or *remote*, according to the proximity of the organs affected. Sympathy of parts is an ultimate fact, perfectly established, but scarcely ever explicable. It is divided by J. Hunter thus:

Sympathy	General Partial	Remote Contiguous Continuous.

Introd. to BLOOD, *&c.*

By Bichât, thus:

Sympathy of	*Animal* sensibility *Animal* contractility	sensible. insensible.
	Organic contractility *Organic* sensibility	sensible. insensible.

Sympathy is also	Healthy. Morbid.

To understand the above table, and the table of the functions given in another place, it is proper to observe, that Bichât applied the term *Life* to any series of vital phenomena subsisting in one part of the body, and *supposed* to be insulated, or at least little connected with the rest. Thus the heart *lives* after the lungs cease to act, therefore he has a "life of the heart;" the brain may survive the lungs in certain states, or the lungs the brain, therefore he has a *life* of the lungs, and a *life* of the brain. In the same way, he has a life of the kidneys, a life of the spleen, of the liver, and, in short, of all the glands. He has crowned this fruitful source of discovery—the substitution of a new meaning for an old word—by speaking of the organic life, the animal life: not at all signifying, by these terms, that any of the life of our body is not animal, but merely that the series of parts which connect us with the external world, possess one kind of properties; and that the parts whose office is not with the external world, but

Of the Understanding.

Whatever be the number and the diversity of the phenomena which belong to human intelligence, however different they appear from the other phenomena of life, though they evidently depend on the soul, it is absolutely necessary to consider them as the result of the action of the brain, and to make no distinction between them and the other phenomena that depend on the actions of that organ. (55) The functions of the brain are absolutely

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with the support and reproduction of the machine, have others totally different. This is all that he means by the terms animal and organic life; the former implying the vital properties of the organs possessed of sensibility, as the nervous and muscular apparatus; the latter embracing all the other organs; besides the sympathetic nervous, and the involuntary muscular system, as an exception from the *animal* organs. In short, the whole matter is very simple: Bichât employs the term *life* instead of "*peculiar vital properties*," and has not, therefore, deviated from this sense of it, whether he speaks of the life of single organs, or of the two great systems. That others have mistaken this language, and thought that he attributed *two* lives to men, must be ascribed to the obscurity of the term *life*, and to the love which all "curious readers" manifest for the wonderful. Bichât allows us at least *ten* lives,—in his sense,—as any person may ascertain by counting them. It happens, indeed, that the animal and organic embrace them all; but whoever reads the first paragraph of Gregory's Conspectus, published first in 1790, will easily learn that this mode of division is neither new nor profound. The novelty and beauty of Bichât's writings on this subject, lie in the many unnoticed properties of the Sympathetic nerve, which he has discovered or collected.

(55) Our author must not here be understood to insinuate that all human intellect depends on organization, as some have erroneously concluded from a superficial inspection of the passage. He states positively, that "they evidently depend on the *soul;*" but he wishes to guard the reader against the error of confounding their *laws*, as modified by the brain, and external matter, with the visionary speculations of the ideologist or metaphysician. Ideology is, no doubt, a part of human physiology; but it has so far outgrown its parent science in point of extent, and is still so far inferior to it in the means of verification, that our author's method of separating them cannot be too much commended. Let the metaphysician always avail himself of the experiments of physiology as far as he is able; but let not the physiologist imagine that he can ever derive a reciprocal assistance from metaphysics. It is possible, however, to transfer credulity from the one extreme to the other;—to yield a faith as implicit to the *probabilities* of the scientific physiologist, as is usually required for the dogmas of pneumatology: and it must be confessed that M. Magendie speaks of the action of the brain in this place, with as little hesitation as elsewhere of the action of a muscle; though that action be as pure an hypothesis as any in metaphysics. What action has this organ on the understanding? it may be

subject to the same laws as the other functions; they develop and go to decay in the progress of age; they are

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asked; or by what process does it think?—The whole doctrine implied is evidently a mere assumption.

We here take no notice of the hypothesis of Gall and Spurzheim which supposes that there are 35 different faculties, all seated on the surface of the brain, and which may *generally* be known externally by eminences on the external table of the cranium, corresponding to them in situation. An eminent anatomist, Dr. Barclay, (*On Life*, p. 376.) asserts, that no supporter of this hypothesis, will undertake to point out eminences in the brain which correspond to these external osseous protuberances; and since this is the case, even granting that the bumps were accurate indices of the so-described faculties, it follows, that their having a residence on eminences of the cerebral surface, is not less imaginary than the faculties themselves. The phrenologists, however, now very properly appeal from anatomy and physiology, to facts; for these must ultimately establish or overthrow the credit of their doctrine. Every one, of course, will judge for himself in this way; as far as my own experience has gone, it has been entirely unfavourable to craniology,—and my trials have both been numerous, and made on persons whose *Internal Faculties* were strongly developed. Indeed, though phrenology places all the finer and more exalted faculties of our nature in some region or other of the forehead, I have repeatedly observed, that the most extensive and available mental powers, as well as the most enthusiastic proclivity for individual pursuits, occur frequently in persons whose forehead is perfectly free of any bump or protuberance whatever. On the whole, fact seems to go against the phrenologist: his doctrine has now been submitted to the experience of the world for nearly thirty years, yet in all that period, so marked by a maniacal rage for scribbling, no one scientific person of *eminence* has appeared in its defence. We count not small authors in a matter so important; for new faiths easily take root among the ignorant, and the latter are by no means unwilling to become either the apostles or the prophets of doctrines which they but imperfectly understand. Surely, if craniology is true, the learned have been singularly backward in shielding it with their approbation. HUFELAND was only a convert to the metaphysics, not to the *signs;* nor has any one, even of its warmest supporters, hitherto so far trusted in this art, as to venture to deliver a history of ALL the prominences in the cranium of select individuals. They adhere to solitary organs, but never give a survey of the entire cranial surface.

CRANIOLOGICAL TABLE OF THE XXXIII FACULTIES,

To which Spurzheim adds—Superstition 34, Phenomena 35.

NAME.	SITUATION.	OFFICE.
I. Order. FEELINGS.		
1. Amativeness.	Space between the mastoid process & the occipital protuberance.	To produce the feeling of sexual desire.
2. Philoprogenitiveness	Cerebral part situated immediately above 1, and corresponds to the general protuberance of the occiput.	To produce the instinctive feeling of attachment to offspring—love of children.

modified by habit, sex, temperament, and individual disposition; they become confused, weakened, or elevated in

NAME.	SITUATION.	OFFICE.
3. Inhabitiveness.	Supposed to be placed above the occipital protuberance immediately over 2, and under 10. C.	To determine the place of dwelling.
4. Adhesiveness.	On each side of 3, and above 2, over the Lambdoïd suture. P.	Love of society,--friendship,—attachment.
5. Combativeness.	Over the inferior and mastoid angle of the parietal bone.	Love of fighting.
6. Destructiveness.	Immediately above the meatus auditorius externus, on the union of the parietal with the squamous plate of the temporal bone.	Impulse to kill,-cruelty.
7. Constructiveness.	Over the spheno-temporal suture at posterior edge of the malar process of frontal bone.	Building, architecture, &c.
8. Covetiveness.	Os Frontis, along its semilunar line.	Desire of acquiring.
9. Secretiveness.	Sphenoidal angle of parietal bones.	Desire of concealing.
10. Self-esteem.	Posterior or sagittal angle of the parietal bone.	Vanity, pride.
11. Love of approbation	Each side of 10 along the Lambdoid suture.	Vanity, love of praise.
12. Cautiousness.	Parietal margin of lambdoid suture between 9 and 11.	Caution, prudence.
13. Benevolence.	Part of frontal bone anterior to the bregma.	Benevolence, kindness.
14. Veneration.	Bregma, or its anterior *frontal* edge.	Piety, devotion, veneration.
15. Hope.	At each side of 14, on the frontal bone. P.	Hope, expectation.
16. Ideality.	Lower than 14 on the frontal bone.	Feeling of perfection, sensibility, inspiration.
17. Conscientiousness.	Parietal bone posterior half. A.	Sense of justice.
18. Firmness.	Before the posterior bregma in parietal angles.	Steadiness, firmness.
II. Order. UNDERSTANDING.		
19. Individuality.	Frontal bone above the superciliary ridge.	General knowledge of Existence.

diseases; the physical injuries of the brain weaken, or destroy them; in a word, they are not susceptible of any explanation more than the other actions of the organ; and setting aside all hypothetical ideas, they are capable of being studied only by observation and experience.

NAME.	SITUATION.	OFFICE.
20. Form.	Root of the nose, or nasal process of the frontal bone at the internal canthus.	Figure, geometry.
21. Size.	Inner edge of sup. arch. P.	Size.
22. Weight.	Behind root of nose, in orbit.	Weight.
23. Colouring.	Over the middle eye-brow. P.	Colour, painting, finery.
24. Locality.	Over the inner limit of each superciliary ridge	Place, travelling, *amor patriæ*.
25. Order.	Over, or in the external limit of the supercilium. P.	Order, arrangement.
26. Time.	Temporal ridge of the frontal bone. C.	Time, accuracy.
27. Number.	External limit of the frontal portion of the orbit.	Arithmetic, mathematics.
28. Tune.	Frontal bone above 25.	Music.
29. Language.	Frontal orbitar plate, protruding eye.	Language—linguists' faculty.
30. Comparison.	Centre of frontal bone above 19, inverted pyramid.	Judgment.
31. Causality.	Same bone at side of 30.	Logic—invention.
32. Wit.	Same level of frontal bone, near its temporal ridge.	Wit.
33. Imitation.	Above 32 in the frontal bone, highest in forehead.	Imitation, mimickry.

A pretender to craniology can scarcely fail. It is only a few ill constituted individuals who want any of the *creditable* faculties described; and in those the eminence *may* be wanting also. Whatever bumps appear in others, the chances are as the number of persons possessing these faculties, to the number which wants them, in favour of the artist. As to the *discreditable* bumps, only one-ninth of the whole, vanity will lead nine persons to lay claim to *creditable*, for one to deny the *discreditable*, faculties. In the extraordinary developments of faculties, chance is still much in his favour; since bumps are very common things, and great faculties uncommon. Lastly, the chances could only be even, or as many misses as hits, if bumps were as often wanting as present; or, bumps being constant, if the faculties were as often absent as present.

Its study not more difficult than that of the other functions.

We must also be cautious in imagining that the study of the functions of the brain is more difficult than that of the other organs, and that it appertains peculiarly to metaphysics. By keeping close to observation, and avoiding carefully any theory, or conjecture, this study becomes purely physiological, and perhaps it is easier than the most part of the other functions, on account of the facility with which the phenomena can be produced and observed.

Of the understanding and of ideology.

The study of the understanding, from whatever cause, is not at present an essential part of physiology; the science which treats particularly of it is *Ideology*. Whoever may wish to acquire an extensive knowledge on this interesting subject should consult the works of Bacon, Locke, Condillac, Cabanis, and especially the excellent book of M. Destutt Tracy, entitled "Elements of Ideology." We will present here only some of the fundamental principles of this science.

The innumerable phenomena which form the intellect of man, are only modifications of the faculty of perception. If they are examined attentively, this truth, which is well illustrated by modern metaphysicians, will be found very clear.

Four modifications of the faculty of perception.

There are four principal modifications of the faculty of perception;

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

2d. The *Memory*, or the faculty of reproducing impressions, or sensations formerly received.

3d. The faculty of perceiving the relations which sensations have to each other,—or the *Judgment*.

4th. The *Desires*, or the *Will*.

Of Sensibility.

Of Sensibility.

What we have said of the sensations generally, is entirely applicable to sensibility; for this reason, we only mention here that this faculty exerts itself in two ways very different. In the first, the phenomenon happens, unknown to us; in the second, we are aware of it, we perceive the sensation. It is not enough that a body may act upon one of our senses, that a nerve transmit to the brain the impression which is produced—it is not enough that this organ receive the impression: in order that there may be really a sensation, the brain must perceive the impression received. An impression thus perceived is called, in *Ideology*, a Perception, or an Idea.

These two modes of sensibility may be easily verified upon ourselves. For example, it is easy to see that a number of bodies have a continual action upon our senses without our being aware of it: this depends in a great measure upon habit. Of two modes of sensibility.

Sensibility is infinitely variable: in certain persons it is very obtuse; in others it is very elevated: generally a good organization keeps between the extremes.

Sensibility is vivid in infancy and youth; it continues in a degree something less marked until past the age of manhood; in old age it suffers an evident diminution; and very old persons appear quite insensible to all the ordinary causes of sensations. Sensibility in different ages.

Of Memory.

The brain is not only capable of perceiving sensations, but it possesses the faculty of reproducing those it has already perceived. This cerebral action is called remembrance, when the ideas are reproduced which have not been long received; it is called recollection, when the ideas are of an older date. An old man who recalls the events of his youth has recollection; he who recalls the sensations which he had last year, has memory, or remembrance. Of memory

Reminiscence is an idea produced which one does not remember having had before. Reminiscence.

In childhood and youth memory is very vivid as well as sensibility: it is therefore at this age that the greatest variety of knowledge is acquired, particularly that sort which does not require much reflection; such as history, languages, the descriptive sciences, &c. Memory afterwards weakens along with age: in adult age it diminishes; in old age it fails almost completely. There are, however, individuals who preserve their memory to a very advanced age; but if this does not depend on great exercise, as happens with actors, it exists often only to the detriment of the other intellectual faculties. Memory in different ages.

The sensations are recalled with ease in proportion as they are vivid. The remembrance of internal sensations is almost always confused; certain diseases of the brain destroy the memory entirely.

Of Judgment.

The judgment is the most important of the intellectual faculties. We acquire all our knowledge by this faculty; without it our life would be merely vegetative; we would have no idea either of the existence of other bodies, or of our own; for these two sorts of notions, like our knowledge, are the consequence of our faculty of judging.

Of the faculty of judging. To judge is to establish a relation between two ideas, or between two groups of ideas. When I judge of the goodness of a work, I feel that the idea of goodness belongs to the book which I have read; I establish a relation, I form to myself an idea of a different kind from that which arises from sensibility and memory.

Reasoning. A continuation of judgments linked together form an inference, or process of reasoning.

Importance of judging justly. We see how important it is to judge justly, that is, to establish only those relations which really exist. If I judge that a poisonous substance is salutary, I am in danger of losing my life; my false judgment is therefore hurtful. It is the same with all those of the same kind. Almost all the misfortunes which oppress man in a moral sense, arise from errors of judgment; crimes, vices, bad conduct, spring from false judgment.

The science of logic has for its end the teaching of just reasoning: but pure judgment, or good sense, and false judgment, or *wrongheadedness*, depend on organization. We cannot change in this respect: we must remain as nature has made us. There are men endowed with the precious gift of finding relations of things which had never been perceived before. If these relations are very important, and beneficial to humanity, the authors are men of genius: if the relations are of less importance, they are considered men of wit, of imagination. Men differ principally by their manner of feeling different relations, or of judging. The judgment seems to be injured by an extreme vivacity of sensations; hence we see that faculty become more perfect with age.

Genius, wit, imagination.

Of the Desire, or the Will.

Will, or desire. We give the name of will to that modification of the faculty of perception by which we form desires. It is generally the effect of our judgment; but what is remarkable, our happiness or our misery are necessarily connected with it. When we satisfy our desires we are happy; but we are miserable if our desires be not fulfilled; it is then necessary to give such a direction to our desires that we may be enabled to obtain happiness. We ought not to desire things which cannot be obtained; we ought to avoid, even with greater care, those things which are hurtful; for in such cases we must be unhappy whether our desires are satisfied or not. Morality is a science which tends to give the best possible direction to our desires.

Happiness or misery.

The desires are generally confounded with that cerebral action which governs the voluntary contraction of the muscles. I think it beneficial to study, to establish the distinction between them.

Such are the four principal shades of the faculty of perception, otherwise called the *simple faculties of the mind.* By combination and re-action upon each other, they constitute the intelligence of man, and of the most perfect animals, with this difference, that in animals they remain nearly in their natural state, whereas man uses them in a different manner, and thence assumes the intellectual superiority which distinguishes him.

Faculty of generalization.

The faculty of generalizing, which consists in creating signs to represent ideas, in thinking by means of these signs, and in forming abstract ideas, is what characterizes the human intellect, and which allows it to extend itself to the prodigious compass manifested in civilized nations; but this faculty necessarily depends on the state of society. A human being separated from the rest of mankind, and who, even in his first years, had no intercourse with his species, (of which there are several examples,) would differ very little from the animals; he would be limited to the four simple faculties of the mind. There are even individuals to whom nature, by a vicious organization, has refused the faculty of employing signs, and forming abstractions, or general ideas: they remain all their lives in a state of stupidity, as is seen in idiots.

Conditions favourable to the display of intellect.

The physical circumstances in which man finds himself placed, have generally a great influence upon the degree of extension of his intelligence. If he procure his subsistence with ease; if he satisfy all the necessities of his organization, he will be in the most favourable state for the cultivation of his mind, and to give the rein to his mental faculties : this happens in civilized countries. But if man can with difficulty provide for his subsistence, and for his other wants, his intelligence, being always directed to one point, will remain in an imperfect state : this happens with savages, enslaved peasantry, &c.

Of Instinct and the Passions.

Of instinct. Animals are not abandoned by nature to themselves; they are all employed in a series of actions; whence results that marvellous whole that is seen amongst organized beings. To incline animals to the punctual execution of those actions which are necessary for them, nature has provided them with *instinct;* that is, propensities, inclinations, wants, by which they are constantly excited, and forced to fulfil the intentions of nature.

Instinct of two sorts. Instinct may exist in two different modes, with or without knowledge of the end. The first is enlightened instinct, the second is blind instinct; the one is particularly the gift of man, the other belongs to animals.

Double design. In examining carefully the numerous phenomena which depend on instinct, we see that there is a double design in every animal: 1st, the preservation of the individual; 2d, the preservation of the species. Every animal fulfils this end in its own way, and according to its organization: there are therefore as many different instincts as there are different species; and as the organization varies in individuals, instinct presents individual differences sometimes strongly marked.

Man has two sorts of instinct. We recognise two sorts of instinct in man : the one depends more evidently on his organization, on his animal state; he presents it in whatever state he is found. This sort of instinct is nearly the same as that of animals.—The other kind of instinct springs from the social state; and, without doubt, depends on organization : What vital phenomenon does not depend on it? But it does not display itself except when man lives in civilized society, and when he enjoys all the advantages of that state.

Animal instinct. To the first, that may be called animal instinct, belong hunger, thirst, the necessity of clothing, of a covering from the weather; the desire of agreeable sensations; the fear of pain and of death; the desire to injure others, if there is any danger to be feared from them, or any advantage to arise from hurting them; the venereal inclinations; the interest inspired by children; inclination to imitation; to live in society, which leads man to pass through the different degrees of civilization, &c. These different instinctive feelings incline him to concur in the established order of organized beings. Man is, of all the animals, the one whose natural wants are most numerous, and of the greatest variety; which is in proportion to the extent of his intelligence: if he had only these wants he would have always a marked superiority over the animals.

When man, living in society, can easily provide for all the wants which we have mentioned, he has then time, and powers of action more than his original wants require: then new wants arise, that may be called social wants: such is that of a lively perception of existence; a want which, the more it is satisfied, the more difficult it becomes, because, as we have already remarked, the sensations become blunted by habit. Social instinct.

This want of a vivid existence, added to the continually increasing feebleness of the sensations, causes a mechanical restlessness, vague desires, excited by the remembrance of vivid sensations formerly felt: in order to escape from this state, man is continually forced to change his object, or to overstrain sensations of the same kind. Thence arises an inconstancy which never permits our desires to rest, and a progression of desires, which, always annihilated by enjoyment, and irritated by remembrance, proceed forward without end: thence arises *ennui*, by which the civilized idler is incessantly tormented.

The want of vivid sensations is balanced by the love of repose and idleness in the opulent classes of society.—These contradictory feelings modify each other, and from their reciprocal re-action results the love of power, of consideration, of fortune, &c., which give us the means of satisfying both.

These two instinctive sensations are not the only ones which spring from the social state; a crowd of others arise from it, equally real, though less important; besides, the natural wants become so changed as no longer to be known; hunger is often replaced by a capricious taste; the venereal desires by a feeling of quite another nature, &c.

The natural wants have a considerable influence upon those which arise from society; these, in their turn, modify the former; and if we add age, temperament, sex, &c., which tend to change every sort of want, we will have an idea of the difficulty which the study of the instinct of man presents. This part of physiology is also scarcely begun. We remark, however, that the social wants necessarily carry along with them the enlargement of the understanding; there is no comparison in regard to the capacity of the mind, between a man in the higher class of society, and a man whose physical powers are scarcely sufficient to provide for his natural wants.

Of the Passions.

Of the passions.

By passion, is generally understood an instinctive feeling become extreme and exclusive. A man of strong passions neither hears, sees, nor exists but through the feeling which agitates him; and as the violence of this feeling is such that it is extremely painful, it has been called *passion* or *suffering*. The passions have the same end as instinct; like them, they incline animals to act according to the general laws of animated nature.

Two sorts of passions.

We see in man passions which he has in common with the animals, and which consist of animal wants, become excessive; but he has others which are displayed only in the social state; these are *social* wants grown to excess.

Animal passions.

The *animal passions* have a twofold design, which we have described in speaking of natural instinct; that is, the preservation of the individual, and of the species.

To the preservation of the individual belong fear, anger, sorrow, hatred, excessive hunger, &c. To the preservation of the species, excessive venereal desires, jealousy; the fury, which is felt when the young ones are in danger, &c.

Nature has made this sort of passions very powerful, and which are equally so in a state of civilization.

Social passions.

The passions which belong to the social state are only the social wants carried to an excess. Ambition is the inordinate love of power; avarice, the love of riches, become excessive; hatred and revenge, that natural and impetuous desire to injure whoever hurts us; the passion of gaming, and almost all the vices, which are also passions, are violent inclinations to increase the feeling of existence; violent love is an elevation of the venereal desires, &c.

Some of the passions are allayed, or extinguished, by gratification; others become more irritated by it: the first sort are, therefore, often the cause of happiness, as is seen in philanthropy and love; whilst the latter sort necessarily cause misery: misers, ambitious and envious people, are examples of the last.

If our necessities develop the intellect, the passions are the principle, or the cause, of every thing *great* which man performs, whether good or bad. Great poets, heroes, great criminals, and conquerors, are men of strong passions.

Seat of the Passions.

Shall we speak of the seat of the passions? Shall we say, like Bichât, that they reside in organic life? or like the ancients, and certain 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 are the result of the action of the nervous system, and particularly of that of the brain; they admit, then, of no explanation. They may be observed, directed, calmed or extinguished; but not explained.*

Of the Voice and Movements.

Functions by which we act upon the bodies which surround us.

The functions that we have hitherto examined, rest all upon the faculty of feeling: by this faculty we know what exists around us, and what we are ourselves. To terminate the history of the relative functions, there remain to be spoken of the functions, by means of which we act upon exterior bodies, produce upon them the changes we think necessary, and express our feelings and ideas to the beings which surround us. These functions are only shades of the same phenomenon, the *muscular contractions:* So that the faculty of feeling on the one part, and muscular contraction on the other, constitute the whole of our *life of relation.* We will first treat generally of muscular contraction, and will then explain its two principal results, *voice* and *motion.*

Of Muscular Contraction.

Muscular contraction.

Muscular contraction, which is likewise named *animal contraction,* is not a vital property, at least according to the manner in which it is necessary to understand this word; it results from the successive or simultaneous ac-

* This should be the proper place to treat of the use of the different *parts* of the brain, in regard to the understanding and instincts; but the subject is still too much involved in conjecture for an elementary work. I have been engaged, at intervals, on experiments directed to this point, and will make the results known as soon as they appear worthy of public notice.

tion of a number of organs; it ought in consequence to be considered as a function.

Apparatus of Muscular Contraction.

The nerves cannot be distinguished into nerves of feeling and nerves of motion.

The organs which concur in muscular contraction are the brain, the nerves, and the muscles. We have no means of distinguishing in the brain those parts which are employed exclusively in sensibility, and in intelligence, from those that are employed alone in muscular contraction. The separation of the nerves into nerves of feeling and nerves of motion is of no use: this distinction is quite arbitrary. Therefore, having spoken above of the brain and the nerves under their anatomical relation, we have nothing more to add: we shall say something of the muscles.

OF THE MUSCLES.

Of the muscles.

The name of *muscular system* is given to the whole muscles, taken collectively.

The form, the disposition, &c., of the muscles are infinitely various. A muscle is composed of a number of *muscular fasciculi,* which are composed of fibres still smaller; these result from fibres of a less volume; at last, by successive division, we arrive at a very small fibre which is no longer divisible, but which perhaps might be so if our means of division were more perfect. This indivisible filament is the *muscular fibre.* There have been many suppositions as to its form, size, position; and the nature of the atoms which compose it. It is longer or shorter according to the muscles to which it belongs. It preserves always a right line, and does not divide nor become confounded with the fibres of the same sort; it is covered with a very fine cellular tissue: soft, and easily torn in the dead body, it, on the contrary, presents in the living one a resistance which, in proportion to its size, is quite astonishing; it is essentially composed of *fibrine* and *osmazome,* receives a great deal of blood, and at least one nervous filament. Some anatomists pretend to explain the manner in which the nerves and the vessels are disposed of after arriving at the tissue of the muscular fibre, but they have said nothing satisfactory on this point.

Of the muscular fibre.

Every muscular fibre is fixed by its two extremities to fibrous prolongations (*tendons, aponeuroses*), which are the conductors of its power when it contracts.

Conditions necessary to muscular contraction.

Muscular contraction, such as takes place in the ordinary state of life, supposes the free exercise of the brain, of the nerves which enter the muscles, and of the muscles themselves. Every one of these organs ought to receive arterial blood, and the venous blood ought not to remain too long in its tissue. If one of these conditions is wanting, the muscular contraction is weakened, injured, or rendered impossible.

Phenomena of Muscular Contraction.

Apparent phenomena of muscular contraction.

When a muscle contracts, its fibres shorten, become hard, with more or less rapidity, without any preparatory oscillation or hesitation; they acquire all at once such an elasticity, that they are capable of vibrating, or producing sounds. The colour of the muscle does not appear to change in the instant of contraction; but there is a certain tendency to become displaced, which the *aponeuroses* oppose.

There have been discussions about the size of a muscle in its contracted and relaxed state: the question does not seem to be resolved in which of these states it is most voluminous; it is happily of small consequence. (56)

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(56) M. Magendie is far from being correct in supposing this fact of the change in the volume of muscles to be of no consequence. Muscular contraction is by far the most important phenomenon of the living body; indeed it is the essence, as we have shown, of the primary idea of life; and we can never be safe even to guess at a theory of contraction, till we have first ascertained the mechanical changes which a muscle undergoes in that state. Of these, change of volume is the most important, and has accordingly engaged the most eminent talents of which Physiology can boast—Borelli, Boerhaave, Glisson, Sauvages, Swammerdam, Haller, Blane, Gordon, and many others, (Hall. El. Phys. iv. 478.). Borelli balanced a man over a triangular prism as a fulcrum, and ordered him to move his lower extremities with vehemence; but no change took place in his equilibrium. Swammerdam included, after his method, a muscle within a cylinder of glass, filled with water, and furnished with a graduated index: he found a frog's heart to increase the water during its contractions, but no change from the contractions of other muscles. Gordon repeated this experiment, after Goddart and Glisson, by introducing his arm into an apparatus of the same kind, of such delicate exactness, that it indicated the systole and diastole of the arteries produced by the wave of blood sent from the heart;—yet no contraction of the muscles of the arm occasioned the least rise or fall of water in the graduated index. It is

The whole of the sensible phenomena of muscular contraction passes in the muscles; but to a certainty no action can take place without the immediate action of the brain and the nerves.

If the brain of a man, or of an animal is compressed, the faculty of contracting the muscles ceases; the nerves of a muscle being cut, it loses all power.

What change happens in the muscular tissue during the state of contraction? this is totally unknown; in this respect there is no difference between muscular contraction and the vital actions, of which no explanation can be given. There is no want of attempts to explain the action of the muscles, as well as that of the nerves and the brain, in muscular contraction: but none of the proposed hypotheses can be received.

Hypotheses of muscular contraction.

Instead of following such speculations, which can be easily invented or refuted, and which ought to be banished from physiology, it is necessary to study in muscular contraction, 1st, the intensity of the contraction; 2dly, its duration; 3dly, its rapidity; 4thly, its extent.

The intensity of muscular contraction, that is, the degree of power with which the fibres draw themselves to-

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scarcely possible, or even conceivable, that in the infinite variety of motions one may employ in the bath, that the diminutions of the relaxed muscles should always be exactly equivalent to the dilatations of those contracted, or *vice versa;* the chances to the contrary are as many millions to unity; yet no contraction of muscles in the bath produces the smallest rise of the water, unless accompanied with locomotion. The objection to the obvious conclusion from hence, advanced by Hooke, and Birch, *Phil. Tr.* iii., amounts to nothing; for blood expressed, by contraction of the flexors, out of the deep veins, does not leave the arm, or the vessel which contains the arm; it merely is driven into other veins of the arm, which are more superficial, and consequently not subjected to pressure from the flexors. Hamberger's method of investigating this subject, consisted in including the arm within a wire or bracelet, and observing the increased pressure occasioned by contracting its muscles: but this phenomenon is fallacious, being produced by the obliquity of direction common to all the long muscles of the fore-arm. It is not easy to see any thing peculiar or advantageous in the substitution of an eel's tail, which was made for the arm, in a Croonian lecture by Sir G. Blane. Had he split the tail of the eel along the spine, then he might have got rid of the doubt above-mentioned, as to the compensating effect of antagonist muscles; but he never seems to have thought of this. In that part of the eel which he employed, the portion from the anus to the tail, no convulsive action whatever, or however produced, made any alteration in the volume of the water, or its index. "It had neither one effect nor other, nor did the muscles at any time occupy either more or less space than at another."—*Blane's Croonian Lectures on Muscular Motion,* p. 13.

gether, is regulated by the action of the brain; it is generally regulated by the will according to certain limits, which are different in different individuals. A particular organization of the muscles is favourable to the intensity of their contraction; this organization is, a considerable volume of fibres, strong, of a deep red, and striated transversely. With an equal power of the will, these will produce much more powerful effects than muscles whose fibres are fine, colourless, and smooth. However, should a very powerfu cerebral influence, or a great exertion of the will, be joined to such fibres, the contraction will acquire great intensity; so that the cerebral influence, and the disposition of the muscular tissue, are the two elements of the intensity of muscular contraction. Intensity of the contraction of muscles.

A very great cerebral energy is rarely found united, in the same individual, with that disposition of the muscular fibres which is necessary to produce intense contractions; these elements are almost always in an inverse ratio. When they are united they produce astonishing effects. Perhaps this union existed in the *athletae* of antiquity; in our times it is observed in certain mountebanks.

The muscular power may be carried to a wonderful degree by the action of the brain alone: we know the strength of an enraged person, of maniacs, and of persons in convulsions.

The will governs the duration of the contraction; it cannot be carried beyond a certain time, however it may vary in different individuals. A feeling of weariness takes place, not very great at first, but which goes on increasing until the muscle refuses contraction. The quick development of this painful feeling depends on the intensity of the contraction and the weakness of the individual. Duration of muscular contraction.

To prevent this inconvenience, the motions of the body are so calculated that the muscles act in succession, the duration of each being but short: our not being able to rest long in the same position is thus explained, as an attitude which causes the contraction of a small number of muscles cannot be preserved but for a very short time.

The feeling of fatigue occasioned by muscular contraction soon goes off, and in a short time the muscles recover the power of contracting. Of fatigue.

Quickness of contractions.

The quickness of the contractions are, to a certain degree, subject to cerebral influence: we have a proof of this in our ordinary motions; but beyond this degree, it depends evidently on habit. In respect of the rapidity of motion, there is an immense difference between that of a man who touches a piano for the first time, and that which the same man produces after several years practice. There is, besides, a very great difference in persons, with regard to the quickness of contractions, either in ordinary motions or in those which depend on habit.

Extent of contractions.

As to the extent of the contractions, it is directed by the will; but it must necessarily depend on the length of the fibres, long fibres having a greater extent of contraction than those that are short.

After what has been said, we see that the will has generally a great influence on the contraction of muscles; it is not, however, indispensable: in many circumstances motions take place, not only without the participation of the will, but even contrary to it: we find very striking examples of this in the effects of habit, of the passions, and of diseases.

Phenomena that ought not to be confounded with muscular contraction.

We must not confound muscular contraction, such as we have now described it, with the modifications which it suffers in diseases, as convulsions, spasms, *tetanus*, wounds of the brain, &c; we must also take care not to confound the contraction of which we are speaking with the phenomena that the muscles present some time after death. These phenomena are doubtless worthy of study; but they do not deserve that importance attached to them by Haller and his disciples; and, above all, they ought not, under the *name of irritability*, to be united with the other modes of contraction which are seen in the animal economy, and particularly with muscular contraction.

Modifications of Muscular Contraction by Age.

Muscular contraction in different ages.

Before the beginning of the second month, the muscles cannot be distinguished from the gelatinous mass which constitutes the embryo: even at this period they scarcely exhibit any of the characters which they present in manhood. They are of a pale grey, and slightly reddish; they receive only a small quantity of blood in proportion to that which they receive afterwards. They grow, and expand along with their size; but this expansion is but trifling, so that at birth they are very slender: we ought

Muscles in the fœtus.

to except however those that concur in digestion, and respiration, which ought to be, and which really are of a much greater size.

Muscles of childhood and youth.

During infancy, and youth, the growth of the muscles is much accelerated, but it is principally in length: on this account young men are round, slender, and agreeable in their form; they are nearly the same in young girls.

Muscles of manhood.

In manhood the forms change again: the muscles become thicker, show themselves under the skin, and increase in volume; the intervals which separate them being left empty, there arise inequalities on the body which give it a very different appearance from that of youth. The tissue of the muscle now becomes more firm; its red colour becomes more deep, even its chemical nature becomes modified; for daily experience teaches us that broth made of the flesh of young animals has a savour, colour, and consistence, quite different from that which is made of the flesh of those that are full grown. The muscles of the full grown animal appear to contain more *fibrine, osmazome*, and *colouring matter* of the blood, and therefore more iron.

Muscles in old age.

The nourishment of the muscles decreases very sensibly in old age. These organs diminish in size, become pale, lax, and unsteady, particularly in the members; the contractility of the tissue is weakened, the fibre becomes tough and difficult to tear; the preparation of muscular flesh is also very different according as the animal is young or old.

Muscular contraction in different ages.

Muscular contraction suffers nearly the same changes as the nutrition of muscles. In the fœtus, it hardly exists, it becomes more active at birth, it increases with rapidity in childhood and youth, it becomes most perfect in manhood, and finishes by being almost destroyed in old age.

OF THE VOICE.

Of the Voice.

By *voice* we understand the sound which is produced in the larynx, at the instant when the air traverses this organ, either to enter or go out of the *trachea*.

In order to understand the mechanism by which the voice is produced and modified, we must say something of the manner in which sound is produced, in which it is propagated and modified in wind instruments, particularly those that have most analogy with the organ of voice.

Of wind instruments. A wind instrument is generally formed of a tube, either straight or bent, in which, by various processes, the air is made to vibrate.

Wind instruments are of two sorts: the one sort are called *mouth* instruments, the other sort *reed* instruments.

Mouth instruments. In the mouth instruments (the horn, trumpet, *trombone*, flageolet, flute, organ,) the column of air contained in the tube is the sonorous body. The air must be caused to vibrate in it in order to produce sounds. For this purpose, the means employed are variable, according to the sort of instrument. The length, the width, the form of the tube, the openings in its sides, or its extremities, the power of the vibrations, and the manner in which they are excited, are the causes of the various sounds of this sort of instruments.—The nature of the matter which forms the sounds has no influence but upon the tone. The theory of these instruments is exactly the same as that of the longitudinal vibrations of cords.* When the physical conditions of such an instrument are known, the sound that it will produce may be determined by calculation; the only obscurity in the theory is about certain points relative to their openings; that is, the manner in which the vibrations are produced in them. There is no evident analogy between this sort of instruments and the voice.

Reed, or pipe instruments. The reed instruments are the most necessary to be known, for the organ of the voice is of this kind; their theory is, unfortunately, much more imperfect than that of the other sort. In this sort of instruments (the clarionet, hautboy, bassoon, voice organ, &c.) we ought to distinguish between the reed, or *anche*, and the body of the tube: their mechanism is essentially different.

A reed is always formed of one, and sometimes of two thin plates, susceptible of a rapid motion, the alternate vibrations of which are intended to intercept and permit, *by turns*, the passage of a current of air: for this reason the sounds which they produce do not follow the same laws as the sounds formed by elastic plates with one end fixed and the other free, which produce sonorous undulations in the open air: in the reed instruments, the reed alone pro-

* Biot, Traité de Physique experimentale et Mathematique, l. ii. c. 9.

duces and modifies the sound. If the plate is long the motions are long, slow, and consequently the sounds are grave; on the contrary, a short plate produces acute sounds, because the alternations of transmission and interception of the current of air are more rapid.

The tone depends on the reed.

When a number of different sounds are intended to be produced by a reed, it is necessary to vary the length of the plate: The bassoon and clarionet players do this when they wish to produce different sounds on the same instrument. We add, as an important circumstance, that the greater or less elevation of sound produced by the instrument, partly depends on the elasticity, the weight, and the form of the little tongue, or plate, and on the force of the current of air; if all these elements are not the same, the length being invariable, the tone will be different.*

Tube of reed instruments.

A reed is never employed alone; it is always fitted to a tube through which the wind passes that has been blown into the reed, and which ought, on this account, to be open at the two extremities. The tube has no influence upon the tone of the music, it acts only upon the intensity, the *timbre*, and upon the power of making the reed *speak*. Those which produce the loudest sounds are of a conical form, increasing in width towards the outer end. If the cone is inverted a dull sound is produced: but if two equal cones are placed base to base, and adapted to a conical tube, the sound acquires fulness and power. Philosophers do not explain these modifications.

Influence of tube in reed instruments.

A column of air which vibrates in a tube is capable of producing only a certain number of determinate sounds; in consequence of this, a reeded tube, when it is long, transmits only with ease those sounds for which it is adapted; it is also necessary to put the reed previously in harmony with the body of the instrument: therefore, when we wish to produce a succession of different sounds from the same tube, we must not only modify the length of the plate, but we must also, in a corresponding manner, modify the length of the tube, and for this purpose are pierced the holes in the sides of clarionets, bassoons, &c.: in stopping or opening them the tube is put in unison with the reed. Another advantage arising from this unison is, that the lips applied to the reed can more easily produce on it the required sound. This influence of tube is very

Unison of the tube with the reed.

* Biot, loc. cit.

considerable in narrow instruments, (clarionets, hautboys;) it is such that the reed could hardly produce the sound, if the tube were not brought to the same tone. In very large tubes (as organs,) the reed vibrates nearly the same as in the open air. In other respects there is nothing certain known of the movements that take place in the air contained in such tubes, when they transmit the sounds produced by the reed. We have seen that it is quite different with mouth instruments.

Apparatus of Voice.

Organs of Voice.

As the passage of air through the larynx is absolutely necessary to the formation of voice, the organs which produce it ought to be considered amongst the number of vocal organs. Many other parts which assist in the production or in the modification of the voice, ought to be considered in the same light; but as we speak of them in another place, we will treat here only of the larynx, which ought properly to be considered as the organ of voice.

Larynx.

The size of the larynx varies according to age and sex; it is placed at the anterior part of the neck, where a small projection is seen, between the tongue and the trachea. It is small in children and women, greater in young men, and still larger in adult age.

The larynx not only produces the voice, but it is also the agent of its principal modifications: on which account, a perfect knowledge of the anatomy of this organ is indispensably necessary to a perfect knowledge of the mechanism of voice. By not having followed this method, we have had hitherto only imperfect or false ideas on this point. As we cannot enter here into all the details of the structure of the larynx, we will only touch upon such as are most necessary to be known, many of which are not yet well understood.

Cartilages of the larynx.

Four cartilages and three fibro-cartilages enter into the composition of the larynx, and form the skeleton of it. The cartilages are the *cricoid*, the *thyroid*, and the two *arytaenoid*. The *thyroid* joins with the *cricoid* by the extremity of its two inferior *horns*. In the living state the *thyroid* is fixed with respect to the *cricoid*, which is contrary to what is generally supposed. Every *arytaenoid* cartilage is articulated with the *cricoid* by means of a surface, which is oblong, and concave in a transverse direction. The *cricoid* presents a surface which is similarly disposed to that of the *arytaenoid*, with this difference, that it is convex in the same direction in which the other is concave. Round the articulation there is a *synovial capsule*, firm before and behind, and moveable without and within. Before the articulation is the *thyro-arytaenoid* ligament; behind is a strong ligamentous band that might be called *crico-arytaenoid*, on account of the manner in which it is fixed.

Being disposed as I have described, the articulation admits only of lateral movements of the *arytaenoid* upon the *cricoid cartilage;* no movement forward or backward can take place, nor a certain movement up and down, mentioned in anatomical books, which none of the muscles is so disposed as to produce. This articulation ought to be considered as a simple lateral *ginglymus*. The fibro-cartilages of the larynx are the *epiglottis*, and two small bodies that are found above the top of the *arytaenoid* cartilages, and that have been called by Santorini, *capitula cartilaginum arytaenoidearum.* (57)

Fibro-cartilages of the larynx.

External muscles of the larynx.

There are a great many muscles attached to the larynx: these muscles are called external; they are intended to move the whole organ, either in carrying it up or down, backward or forward, &c. The larynx has also other muscles whose use is to give a movement to the different parts in respect of each other; these muscles have been called internal; they are, 1st, the *crico-thyroid*, the use of which is not, as has hitherto been believed, to lower the *thyroid* upon the *cricoid*, but on the contrary, to raise the *cricoid* towards the *thyroid*, or in making it pass a little below its inferior edge; 2d, the muscles *crico-arytaenoideus posterior*, and the *crico-arytaenoideus lateralis*, the use of which is to draw outwards the *arytaenoid* cartilages, in separating them from one another; 3d, the *arytaenoid* muscle, which draws the *arytaenoid* cartilages together; 4th, the *thyro-arytaenoideus*, a knowledge of which is more important than that of all the muscles of the larynx, because its vibrations produce the vocal sound. (58) This muscle forms the lips of the *glottis*, and the inferior, superior, and

Internal muscles of the larynx.

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(57) See Santorini's Work, p. 97.

(58) The author probably means: "because it regulates the vibrations which produce the vocal sound." The present expression seems a slip of the pen.

Muscles of the epiglottis. lateral sides of the ventricles of the larynx; 5th, lastly, the muscles of the *epiglottis*, which are the *thyro-epiglottideus*, the *arytaeno-epiglottideus*, and some fibres that may be considered as the vestige of the *glosso-epiglottideus* muscle that exists in some animals, whose contraction has an influence upon the position of the *epiglottis*.

Mucous membrane of the larynx. The larynx is covered within by a mucous membrane. This membrane, in passing from the *epiglottis* to the *arytaenoid*, and *thyroid* cartilages, forms two folds, called lateral ligaments of the *epiglottis:* they concur in the formation of the superior and inferior ligaments of the *glottis*.

Arytaenoid Gland. In the substance of the *epiglottis*, and behind it, are found a great number of mucous follicles, and some mucous glands; within the mass of the ligaments of the *epiglottis* there exists a collection of those bodies that have been very improperly called *arytaenoid* glands.

Epiglottic gland. Between the *epiglottis* behind, and the *os hyoides* and *thyroid* cartilage before, there is seen a considerable quantity of the adipose cellular tissue which is very elastic, and similar to that which exists near certain articulations. Uses of the epiglottis gland. There has been no use assigned to this body: I believe it serves to facilitate the frequent movements of the *thyroid* cartilage, upon the posterior face of the *os hyoides;* and to keep the *epiglottis* separated from the upper part of this bone, whilst, at the same time, it provides it with a very elastic support, favourable to the action of the *fibro-cartilages* in the production of the voice, or in deglutition.

Vessels and nerves of the larynx. The vessels of the larynx present nothing remarkable. It is not so with the nerves of this organ; their distribution merits a careful examination. There are four of these nerves: the superior *laryngeal*, and the inferior.

The recurrent nerve is distributed to the posterior *crico-arytaenoid*, to the lateral *crico-arytaenoid*, and *thyro-arytaenoid;*—none of the ramifications of this nerve go to the *arytaenoid*, or to the *crico-thyroid*, muscles. On the contrary, the superior nerve of the larynx goes to the *arytaenoid* muscle, which it provides with a considerable branch; and to the *crico-thyroid*, to which it gives a small filament, more remarkable for the distance it proceeds than for its size. In certain cases this filament does not exist: the external branch of the nerve of the larynx is then of a larger size. The remainder of the filaments of the laryngeal nerves are distributed to the epiglottis, and to the mucous membrane which covers the entrance of the larynx: this part possesses an extraordinary sensibility.

Of the glottis.

The interval which separates the *thyro-arytaenoid* muscles, and the *arytaenoid* cartilages is called glottis. In the dead body the glottis presents the appearance of a longitudinal slit of about eight or ten lines long, and two or three wide; it is wider behind than before; here the two sides meet at the point of their insertion into the *thyroid* cartilage. The posterior extremity of the glottis is formed by the *arytaenoid* muscles.

Ligaments of the glottis.

If the *arytaenoid* cartilages are brought together so as to touch on their internal faces, the glottis is diminished nearly a third of its length; it then presents a slit which is from five to six lines long, and from half a line to a line broad. The sides of this slit are called the *lips of the glottis.* They present a sharp edge turned upward and inward; they are essentially formed by the *arytaenoid* muscle, and by the ligament of the same name, which as an *aponeurosis* covers the muscle to which it adheres strongly, and which, being itself covered by the mucous membrane, forms the thinnest parts or edge of the *lip.* These lips of the glottis vibrate in the production of the voice; they might be called the *human reed.* Above the inferior ligaments of the glottis are the ventricles of the larynx, the cavity of which is larger than it seems at first sight; the superior, inferior, and external sides of it are formed by the *thyro-arytaenoid* muscle, turned upon itself; the extremity, or anterior side is formed by the *thyroid* cartilage. By means of these ventricles, the lips of the glottis are completely isolated upon their upper side.

Ventricles of the larynx.

Superior ligaments of the glottis.

Above the opening of the ventricles we see two bodies, which, in their manner of being disposed, have a great deal of analogy with the vocal chords, and which form a sort of second glottis above the first; these bodies are called the *superior ligaments of the glottis.* They are formed by the superior edge of the *thyro-arytaenoid* muscle, a little adipose cellular tissue, and the mucous membrane of the larynx, which covers them before penetrating into the ventricles. These observations are easily made upon the larynx of dead bodies. I do not believe that the glottis of a living person has ever been examined, at least to my knowledge, there has been nothing written on this subject;(59) but when those of animals, as of dogs, are examined, they contract and enlarge alternately; the *arytaenoid* cartilages are directed outwards when the air penetrates into the lungs, and in the instant when the air passes out they come close together.

Mechanism of the Production of Voice.

Mechanism of Voice.

If we take the trachea and the larynx of an animal, or of a man, and blow air strongly into the trachea, directing it towards the larynx, there is no sound produced, but only a slight noise, resulting from the pressure of the air against the sides of the larynx. If, in blowing, we bring together the *arytaenoid* cartilages, so that they may touch upon their internal face, a sound will be produced, something like the voice of the animal to which the larynx used in the experiment belongs.

Experiments upon Voice.

The sound will be dull or sharp according as the cartilages are pressed more or less forcibly together; its intensity will be more or less according to the intensity of the air. It is easily seen, in this experiment, that the sound is produced by the vibrations of the inferior ligament of the glottis.

Both man and the animals are deprived of voice by making an opening below the larynx: the voice is reproduced if the opening is closed mechanically. I know a person who has been in this situation for four years; he cannot speak without pressing a cravat strongly against a fistulous opening in the larynx. The same thing takes place when the larynx is opened below the inferior ligaments of the glottis.

But if a wound exists above the glottis; if the epiglottis and its muscles are affected; if the superior ligament of the glottis, even if the superior aspect of the *arytaenoid* cartilages are injured, the voice continues.

Lastly, the glottis of an animal being laid bare in the instant that it cries, shows very well that voice is produced by the vibrations of the vocal chords.* This, I think, is enough to prove, beyond all doubt, that the voice is formed in the glottis by the motion of its inferior ligaments.

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

(59) See Dodart's Memoir, and Bichât. Our author has done much to illustrate the difficult physiology of the glottis, not merely by instituting his own experiments, but by reviving many of authors now forgotten.

This fact being established, is it possible, on physical principles, to account for the formation of the voice? I will here give the explanation which appears to me the most probable. The air being pressed from the lungs, proceeds in a pipe of considerable size; this pipe very soon becomes contracted, and the air is forced to pass through a narrow slit, the two sides of which are vibrating plates, which permit and intercept the air, like the plates of reeds, and which ought, in the same manner, by these alterations, to produce sonorous undulations in the transmitted current of air.

Contraction of the thyro-arytaenoid muscles necessary to Voice.

But in blowing into the trachea of a dead body, why does it not produce a sound like that of the human voice? why is the palsied state of the internal muscles of this organ followed by the loss of the voice? why, in a word, is an act of the will necessary to produce the vocal sound? The answer to this is not difficult. The ligaments of the glottis have not the faculty of vibrating like the plates of reeds, except the *thyro-arytaenoid* muscles are contracted; and, therefore, in every case in which the muscles are not contracted, the voice will not be produced.

Experiments on the Voice.

Experiments performed on animals are perfectly in unison with this doctrine. Divide the two recurrent nerves, which, as we formerly said, are distributed to the *thyro-arytaenoid* muscles, and the voice will cease. If only one is cut, the voice will be only half lost.

I have seen, however, a number of animals, in which the two recurrent nerves had been cut, cry very loud when they suffered severe pain. Those sounds were very similar to the sounds that would be produced mechanically with the larynx of the animal when dead, by blowing into the trachea, and bringing together the *arytaenoid* cartilages: this phenomenon is easily understood by the distribution of the nerves of the larynx. The recurrents being cut, the *thyro-arytaenoid* muscles do not contract, and thence results *aphonia*, or the loss of voice; but the *arytaenoid* muscle, that receives its nerves from the superior *laryngeal*, contracts, and brings together, in the instant of a strong expiration, the *arytaenoid* cartilages, and the slit of the glottis becomes sufficiently narrow for the air to throw the *thyro-arytaenoid* muscles, though they are not contracted, into vibration.

Intensity or Volume of the Voice.

Intensity of the Voice. The intensity of the voice, like that of all other sounds, depends upon the extent of the vibrations.

The vibrations of the *vocal chords* will be in proportion to the force with which the air is expelled from the breast; and the longer the chords are, that is, the more voluminous the larynx is, the more considerable will be the extent of the vibrations. A strong person, with a large chest, and a larynx of large dimensions, presents the most advantageous condition for the intensity of the voice. If such a person becomes sick, his voice, on account of his weakness, loses much of its intensity, because it is no longer expelled with the same force from the chest.

Children, women, and eunuchs, whose larynx is proportionably less than that of a man in adult age, have also much less intensity of voice.

In the ordinary production of the voice, it results from the simultaneous motions of the two sides of the glottis: were one of these sides to lose the faculty of causing the air to vibrate, the voice would lose, necessarily, half its intensity, the force of expiration being the same. This may be proved in cutting one of the recurrent nerves of a dog, or in paying attention to the voice of a person who has had a complete attack of *hemiplegia*.

Timbre, or Tone of the Voice.

Tone of the Voice. Every individual has a particular tone of voice by which he is known; there is also a particular tone which belongs to the different sexes and age. The tone of the voice presents an infinite number of modifications: upon what circumstances do these depend? This is unknown. The feminine tone, however, which is found in children, and eunuchs, generally agrees with the state of the cartilages of the larynx. On the contrary, the masculine tone which women sometimes possess, appears to be connected with the state of these cartilages, and particularly with that of the *thyroids*. *Timbre*, or tone, is a modification of sound, of which philosophers have by no means given an exact explanation.

Of the extent of the Voice.

Extent of the Voice.

The sounds which the human larynx is capable of producing are very numerous. Many celebrated authors have endeavoured to explain the manner of their formation; but they have rather given us comparisons than explanations. Thus *Ferrein* supposed that the ligaments of the glottis were chords, and so he 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 a *horn blower*, to the lips of a person who whistles.

These explanations are badly founded, for they rest only on a superficial consideration of the larynx in the dead body, whereas they ought to have been supported by the study of the larynx, and by an attentive examination of that organ in the living state: I have endeavoured to supply what was wanting in this respect; the result of my studies I here present.

Experiments upon the Voice.

I laid bare the glottis of a noisy dog by cutting between the thyroid cartilage and the *os hyoides*, and I saw that when the sounds are grave, the ligaments of the glottis vibrate in their whole length, and that the expired air passes out in the whole length of the glottis.

In acute sounds, the ligaments do not vibrate in their anterior part, but only in the posterior, and the air passes only in the part which vibrates: the opening is therefore diminished. Lastly, when the sounds are very acute, the ligaments present vibrations at their arytaenoid extremity only, and the expired air passes only by this portion of the glottis. It appears that the extreme limit of acuteness in sounds happens when the glottis closes entirely, and the air can no longer pass through the larynx.

The use of the arytaenoid muscle being principally to close the glottis in its posterior extremity, it ought to be the principal agent in the production of acute sounds. In wishing to know what effect the section of the two laryngeal nerves would have upon the voice, as they give motion to this muscle, I found that the voice of an animal loses almost all its acute sounds; it acquires, besides, a constant gravity which it had not formerly.

The analogy of the structure of the larynx in man and in the dog, is too strongly marked, to leave any doubt that the same phenomena happen in both. One circumstance ought to have a great influence upon the tones of the voice, and this is the contraction of the arytaenoid muscles. The more forcibly these muscles contract, and the more their elasticity increases, they will be the more susceptible of vibrating rapidly, and producing acute sounds; in proportion as they are less contracted the sounds will be graver.

Approximate explanation of the tone of the Voice.

We may also suppose that the contraction of these muscles has a powerful influence in closing the glottis, particularly in its anterior half. It therefore appears evident that the larynx represents a reed with a double plate, the tones of which are so much more acute as the plates are shortened, and grave in proportion as they are long. But though this analogy may be just, we must not conclude that there is a complete identity.

In fact the ordinary reeds are composed of rectangular plates fixed at one side and free on the three others, whilst the vibrating plates of the larynx, which are also almost rectangular, are fixed on three sides and free only on one. Besides, the tones of ordinary reeds are raised or sunk by varying their length: In the plates of the larynx it is the breadth which varies. In a word, there have never been employed in musical instruments any reeds whose moveable plates could vary every instant in thickness and elasticity, like the ligaments of the glottis: so that we may easily see that the larynx can produce the voice, and vary its tones, like reeds, but we cannot assign with rigour all the particular modes of its action.

It has been hitherto believed that the tube which carries the air to the reed, or the *porte-vent*, has no influence upon the nature of the sound produced. M. Biot gives an observation of M. Grenié, which proves the contrary. It is not, then, impossible that the elongation, or the shortening, of the trachea, which performs the office of *porte-vent* to the larynx, may have an influence upon the production of the voice, and its different tones.

Uses of the vocal Tube.

We have examined the reed of the organ of voice; we shall now consider the tube that the vocal sound traverses after having been produced. In proceeding from below upwards, the tube is composed, 1st, of the interval between the epiglottis before, its lateral ligaments upon the sides, and of the posterior side of the pharynx; 2dly, of the pharynx behind and laterally, and of the most posterior part of the base of the tongue before; 3dly, sometimes of the mouth, and sometimes of the nasal cavities; at other times of these two cavities together.

This tube, capable of being prolonged or shortened, of being made wider or narrower; being susceptible of assuming an infinite variety of forms, ought to be very capable of performing all the functions of the body of a reed instrument;—that is, to be capable of harmonizing with the larynx, and of thus favouring the production of the numerous tones of which the voice is susceptible; of increasing the intensity of the vocal sound, by taking a conical form, with the base outwards; of giving a roundness and agreeableness to the sound, by suitably disposing its exterior opening, or by almost entirely shutting it, &c.

Until the influence of the tube of reed instruments has been determined with precision, it is evident that we can form only probable conjectures respecting the influence of the tube of the organ of voice. In this respect we can make only a small number of observations, which relate particularly to the most apparent phenomena.

Shortening of the vocal tube.

A. The larynx is raised in the production of acute sounds; it is lowered, on the contrary, in the formation of those that are grave; consequently, the vocal tube is shortened in the first case, and lengthened in the second.

We suppose that a short tube is more favourable to the transmission of acute sounds, whilst a long one is more so for those that are grave. The tube changes its length at the same time that it changes its breadth; and this is remarkable, as we have seen above that the breadth of the tube has a great influence upon its facility of transmitting sounds.

Lengthening of the vocal tube.

When the larynx descends, that is, when the vocal tube is prolonged, the thyroid cartilage descends, and removes from the os hyoides the whole height of the *thyro-hyoid* membrane. By this separation the gland of the epiglottis is carried forward, and places itself in the cavity of the posterior aspect of the os hyoides; this gland draws after it the epiglottis: from this results a considerable enlargement of the inferior part of the vocal tube.

The contrary phenomenon happens when the larynx is raised. The thyroid cartilage then rises, and becomes engaged behind the os hyoides,* by displacing and pushing backward the epiglottid gland; this pushes the epiglottis, and the vocal tube is much contracted. By imitating the motion upon the dead body, we may easily ascertain that the narrowing may proceed to five-sixths of the breadth of the tube. Now, we adapt a large tube to a reed for the purpose of producing grave sounds; on the contrary, it is a narrow tube which is generally employed for the purpose of transmitting acute sounds. We can, then, to a certain degree, account for the utility of the changes of breadth which take place in the inferior part of the vocal tube.

Use of the ventricles of the larynx.

B. The presence of the ventricles of the larynx immediately above the inferior ligaments of the glottis, appears intended to isolate those ligaments, so that they may vibrate freely in the air. When foreign bodies enter the ventricles, or when a false membrane, or mucosities are formed, the voice is generally extinguished, or much weakened.

Use of the epiglottis.

C. From its form, its position, its elasticity; from the motions which its muscles impress upon it, the epiglottis appears to belong essentially to the apparatus of the voice; but what are its uses? We have already seen that it contributes powerfully to the narrowing of the vocal tube; it may be supposed that it has a more important function.

M. Grenié, who has just discovered so ingenious and useful a modification of the reeds, did not arrive all at once at the result which he at last attained; he succeeded by a series of intermediate effects; at a certain period of his labour, he wished to augment the intensity of a sound, without changing any thing in the reed. To succeed, he was obliged gradually to augment the force of the current of air; but this augmentation, in rendering the sounds strong, caused them to rise. To prevent this inconvenience, M. Grenié found no better means than to place obliquely in the tube, immediately under the reed, a supple, elastic tongue, nearly such as we see the epiglottis above the glottis; whence we may suppose that the epiglottis gives man the faculty of increasing the vocal sound, without letting it rise.

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

Influence of vocal tube on the intensity of voice.

D. The vocal tube has visibly an influence upon the intensity of the voice. The most intense sounds which the voice can produce cause the mouth to be opened very wide, the tongue to be drawn a little back, and the *velum* of the palate raised into a horizontal position, and to become elastic, closing all communication with the nostrils.

In this case the pharynx and the mouth evidently perform the office of a *speaking trumpet*, that is to say, they represent very exactly *a tube with a reed*, which increases in wideness outwards, the effect of which is to augment the intensity of the sound produced by the reed. If the mouth is in part closed, the lips carried forward and turned towards each other, the sound will acquire rotundity and an agreeable expression; but it will lose part of its intensity: this result is easily explained after what we have said of the influence of the form of tubes in reed instruments.

For the same reasons, whenever the vocal sound passes into the nose, it will become dull, for the form of the cavities of the nose is well fitted for diminishing the intensity of sounds. If the mouth and nose are shut at the same time no sound can be produced.

Influence of the tube upon the expression of the voice.

E. We have seen, in considering the production of voice, that a great number of modifications relative to expression (*timbre*,) arise from changes of the thickness, and of the elasticity of the lips of the glottis. The tube may produce a number of others, according to its different degrees of length or breadth; according to its form, the contraction of the pharynx, the position of the tongue, or of the velum of the palate; according as the sound passes wholly or in part through the mouth, or the nose, or both together; according to the individual disposition of the mouth or nose; the existence or non-existence of teeth; the size of the tongue, &c.; the expression of the voice is continually modified according to all these circumstances. For example, whenever the sound traverses the nasal cavities, it becomes disagreeably *nasal*.

Influence of the nasal cavities upon the voice.

Those persons are mistaken, who think that the intensity of vocal sound may be augmented by repercussion, in passing through the nasal cavities; these cavities produce quite a contrary effect. Whenever the voice is introduced into them, from whatever cause, it becomes dull.

F. Besides the numerous modifications which the tube of the vocal organ causes in the intensity and the expression of the voice, in alternately permitting or intercepting its productions: there is another very important kind of modification produced by it. By means of this the vocal sound is divided into very small portions, each possessing a distinct character, because each of them is produced by a distinct motion of the tube. This sort of influence of the vocal tube is called the *faculty of articulating*, which presents, besides, an infinite variety of individual differences suitable to the peculiar organization of the vocal tube.

We have hitherto treated of the human voice in a general manner; we now proceed to speak of its principal modifications: namely, the cry or native voice; the voice properly so called, or acquired voice; speech, or articulate voice; singing, or *appreciable* voice.

Of the Cry, or Native Voice.

Of the Cry. The cry is a sound which cannot be appreciated; it is, like all those sounds produced by the larynx, susceptible of variation in tone, intensity, and expression. The cry is easily distinguished from all other vocal sounds; but as its character depends upon the expression, it is impossible to account physically for the difference between it and the latter. Whatever is the condition of man, or whatever his age, he is capable of crying. The new-born child, the idiot, the person deaf from birth, the savage, the civilized, the decrepit old man, all are capable of producing cries. We ought, then, to consider the cry as particularly attached to organization; indeed we may be convinced of this in examining its uses.

Use of the Cry. By the cry we express vivid sensations, whether they proceed from without or within; whether they are agreeable or painful:—there are cries of pleasure and of pain. By the cry we express our most simple instinctive wants, the natural passions. There is a cry of fury, another of fear, &c.

The social wants and passions, not being an indispensable consequence of organization, and the state of civilization being necessary for their development, they have no peculiar cry. The cry comprehends, generally, the most intense sounds that the organ of voice can produce; its expression has often something in it which offends the ear, and it has a strong action upon those who are near it.

By means of the cry, important relations are established among mankind. The cry of joy inclines to joy; the cry of pain excites pity; the cry produced by terror causes fear, even in those at a distance, &c. This sort of language is found in most animals; it is almost the only language which has been given them; the song of birds ought to be considered as a modification of their cry.

Of acquired Voice, or Voice properly so called.

In the usual state of man, that is, when he lives in society, and when he is possessed of the faculty of hearing, he knows, from earliest youth, that mankind utter sounds which are not cries; he very soon finds that he can produce the same sort of sounds with his larynx, and immediately, what is called *acquired voice*, is developed in him, by the effect of imitation, and the advantages he derives from it. A deaf child cannot make any remark with regard to sound, and therefore he never acquires it. There seems to be no difference between the voice and the cry, except in intensity and expression, for it is likewise formed of inappreciable sounds, or of sounds whose intervals are not exactly distinguished by the ear. Of acquired Voice.

Since the voice is the consequence of hearing, and of an intellectual process, it cannot be developed if those circumstances, by which it is produced, do not exist. In fact, children born deaf, who have never had any idea of sound; idiots, that establish no relation between the sounds which they hear, and those which their larynx can produce, have no voice, though the vocal apparatus of both may be fit to form and modify sounds as well as that of individuals perfectly formed.

For the same reason those whom we improperly term *savages*, because they have been found wandering in forests since their infancy, can have no voice; the understanding not being developed in a solitary state, but only in social life.

The expression, *(timbre)*, the intensity, the tone of the voice, are susceptible of numerous modifications on the part of the larynx; the vocal tube also exerts a powerful influence upon the voice: speech, and singing, are only modifications of the social voice.

It is difficult, perhaps impossible, to say how man has been able to represent his intellectual acts by modifica- Of Speech.

tions of the voice, how he has been able to compose languages, and above all how he could compose the alphabet. This knowledge would be, without doubt, curious and useful, but it is not indispensable, and besides it does not belong to physiology: the mechanism of language alone is what we have to explain.

A language is composed of words, and words are the signs of ideas; but words themselves are formed by the letters, or the sounds of the alphabet, which are, generally, modifications of the voice.

The letters are divided by grammarians into vowels and consonants; this is not a suitable distinction for physiologists.

Of Letters. Letters ought to be divided into those that are real modifications of the voice, and into those that may be formed independently of the voice.

Vocal Letters. The letters which belong to the voice are, for European languages, *a*, very open, as in *hall*, English; *â* in *hâle*, French; *a*, *é*, *è*, and *e mute*, French: *i*, *o*, open, Italian: *o*, *eu*, *u*, French; *u*, Italian. Each of these letters may suffer two modifications, which are expressed by saying they are 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.

The formation of the vowels causing the vocal tube to be open, depends, therefore, upon the form which this takes during the time that the voice is uttered. The vocal consonants suppose that the tube is shut, and they result from the manner in which the tube is opened in the instant when voice is formed: the production of these last letters is then instantaneous. (60)

Letters which are not Vocal. The other letters are *f* and *v*, the two sounds of the *th*, English; *s* and *z*, *ch*, *j*, *r*, *h*, and *x*, Spanish; or *χ*, Greek.

The character of these letters is that of their being produced by the friction of the air against the sides of the mouth, and by being consequently independent of the vo-

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(60) An excellent discussion of the principles of articulation may be found in Brewster's Encyclopædia. It was written by the late Dr. Gordon, and may be perused along with the present, and Haller's chapter on the subject, with great advantage. Some of its conclusions, however, appear to be premature.

cal sound, and the capability of being prolonged whilst the air continues to pass from the lungs.

Pronunciation.

Every letter, vowel, or consonant, is produced by a particular disposition or motion of the vocal tube; but for one sort the tongue is the principal agent of formation; for another it is the teeth; others again are formed by the lips; whilst, for the production of others, the air must traverse the nasal cavities.

Pronunciation requires, then, a proper conformation of the vocal tube. Should it be impaired, should there be any perforation in the palate, any loss of teeth, should the tongue be swelled or paralyzed, &c., the power of articulation is altered, and may even become impossible.

Low Voice

The noise alone produced by air in traversing the mouth, is sufficient for pronunciation; as it happens when we speak very low. Persons who have completely lost their voice, pronounce still sufficiently distinct to be heard at a certain distance. (61)

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(61) A beautiful proof of this assertion occurred lately in H. R—ss, an acquitted felon, who happening to be re-committed for a new trial, attempted, by cutting his throat while in prison, to anticipate that punishment of his crime which, probably, seemed now inevitable. The instrument (a razor), had completely divided both the larynx, a little above the cricoid cartilage, and the œsophagus at the same point; so that whatever was introduced into the mouth escaped by the external wound. Nature proved active, the law inadequate to his conviction; but as the divided parts had retracted to more than three inches distance, no effort of the surgeon was sufficient to re-unite them. In short, the cephalic extremities of the air and alimentary tubes became, in the process of recovery, obliterated, while the culprit, liberated from all dread of prison or gallows, still continues to breathe and feed, with little inconvenience, from their still pervious thoracic extremities, the matters destined to make their transit by the œsophagus, being conveyed into it by means of a tube. The following facts which have been observed in the man, who is now quite well, establish the assertion of our author, "and are otherwise interesting (says Dr. Gairdner, the narrator,) in a physiological point of view."

1. "During each meal, and immediately after it, there is a very profuse discharge of saliva from the mouth, amounting to from five or six, to eight ounces, or even more, and generally most profuse when the food is very hot.

2. "He still preserves the sense of smelling in a very considerable degree; probably from his possessing the power of producing a current of air through the nostrils, by the action of the muscles of the mouth and tongue.

3. "He possesses also a power of articulating to a certain extent—very limited, of course, and without the slightest degree of *laryngeal* sound. This power must also be owing to his taking a little air into his mouth, by the muscles of which it is expelled in the attempt at pronunciation. For

By combining letters differently, and in various numbers, we form compound sounds, which are words.—The formation of words is different according to different languages. In those of the north, the consonants are numerous; but this is not the reason of their being disagreeable to the ear, and difficult to pronounce. Vowels are more numerous in the languages of the south, and they are generally soft and harmonious.

Of Accent. It is not a sound always the same which serves as a base for pronunciation; articulate voice rises, falls, changes in intensity and expression, in a different manner, according to each language. The mode of these changes constitutes *accent*, or the pronunciation peculiar to each country.

To *articulate*, to *pronounce*, is not to *speak*. A bird pronounces words, and even phrases, but it does not speak. Man alone is endowed with *speech*, which is the most powerful means of expression possessed by the understanding; he alone attaches a meaning to the words that he pronounces, and to the arrangement that he gives them: and, had he no intelligence, he would have no speech. The greater part of idiots cannot speak; they articulate sounds vaguely, which neither have, nor can have any signification.

Of Singing.

The voice of song differs from the other sounds produced by the larynx, insomuch as it is formed of appreciable sounds, the intervals of which are easily distinguished by the ear, and which can be put in unison. These characters do not exist, either in the cry, or in the voice of speech, the sounds of which are not appreciable. Dodart advanced that, in singing, the larynx experiences a sort of oscillation upwards; but this assertion is not confirmed by experience. In singing, it is probable that the ligaments of the glottis take a particular disposition which

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instance, if a question be put to him which may be answered by the monosyllable YES, his tongue, and teeth, and lips, perform that succession of actions, which in the sound state of the parts, would be necessary for its distinct articulation, and the word, or rather the letter S, with which it concludes, is heard as in a whisper."—*Edin. Med. and Surg. Journ. July,* 1820.

fits them for the production of appreciable sounds. We remark very important individual differences, with regard to extent, intensity, expression, &c. in singing.

Extent of the voice in singing.

An ordinary voice has about nine tones between the gravest and the most acute sound; the most extensive voice hardly passes two octaves in sounds which are distinct and full.

There are two sorts of voices, grave and acute; the difference between them is about an octave.

Grave voices.

Grave voices generally belong to full grown men; however, those who have the gravest voices can form acute sounds by *shrilling*, or *falsetto*.

Acute voices.

Acute voices are those of women, children, and eunuchs. By adding all the tones of an acute, to those of a grave voice, they make about three octaves. It does not appear that ever any individual had a voice so extensive as this in pure and agreeable sounds.

Musicians establish other distinctions in base voices: as *high counter*, *tenor*, *base*, &c.

Different sorts of voices.

But the differences which exist in different sorts of voices do not all depend on the extent. There are strong voices whose sounds are strong and noisy; soft voices whose sounds are soft and sweet; fine voices, whose sounds are full and harmonious: there are voices that are just, others that are false; there are some flexible and light; others hard and heavy. Some have their fine sounds irregularly distributed; some in the *base*, others in the *treble*, some in the *medium*. Singing, the same as voice and speech, belongs to the state of society; it supposes the existence of hearing and intellect. It is generally employed to paint the instinctive wants, the passions, the different states of the mind. Joy, sorrow, love happy or unfortunate, produces different sorts of singing.

Of articulate singing.

Singing may be articulate. Then, in place of simply expressing feelings, it becomes a means of expression of most of the acts of the mind, but particularly of those that are connected with the social passions.

Of declamation.

Declamation is a particular species of singing; the intervals of the tones only are not harmonic, and the tones themselves are not completely appreciable. Declamation appears to have differed much less from singing amongst the ancients, than with the moderns; perhaps it had some analogy with what we call recitative in our operas. The southern languages being very much accentuated, that is, varying greatly in their tone, in simple pronunciation, are very proper for being sung.

Voice by inspiration.

All the modifications of voice, which we have just studied, are produced when the air passes from the chest.—The voice may also be produced in the instant the air traverses the larynx to pass into the trachea; but this voice by *inspiration* is hoarse, unequal and of small extent; any variations in its tones are produced with difficulty; indeed even by the characters of the phenomenon, we may suppose that it does not pass according to the ordinary laws of the economy. We can also speak and sing during inspiration. The modifications which the lips of the glottis suffer during the production of the voice by inspiration are not known.

Art of Ventriloquists. (62)

Since man may thus vary almost to infinity, the appreciable, and inappreciable sounds of his voice, as he may change in a thousand different ways according to his will the intensity, the expression, &c., nothing is more easy for him than to imitate the different sounds he hears: this in fact he performs in many circumstances. Many persons imitate perfectly the voice and pronunciation of others; actors, for example. Hunters imitate the different cries of the game, and thus succeed in decoying it into their nets.

This faculty possessed by man of imitating the different sounds he hears has given rise to an art; but the persons who exercise this art, and who are called ventrilo-

(62) Ventriloquism is not exactly an imitative process, though certainly depending much on that faculty. Thus Matthews, the celebrated mimic, is a tolerable ventriloquist, and derives much of his success in it from mere imitation. Still Matthews, and all others, avail themselves of another principle; namely, the imperfect manner in which man, their auditor, judges of the angle of position by the ear. When we shut our eyes, we have a very imperfect and often erroneous idea of the place from which the sound issues. The ventriloquist, therefore, or more properly to speak, the *Alioloquist*, turns his face in the direction, and approaches it to the object, from which he designs to counterfeit a sound issuing; or at least, places himself so as to make a very small angle with the line drawn from the spectator to the object; and in one or other of these three ways, or by them altogether, a well imitated sound seems to the spectator to issue from the object. When Matthews makes the puppet speak from within a box, he always previously bends down his head as if to listen; it is thus he diminishes the angle of position.

quists, have no organization different from that of other men: they require only to have the organs of voice and speech very perfect, in order that they may readily produce the necessary sounds.

The basis of this art is easily understood. We have found by experience, instinctively, that sounds are changed by many causes: for example, that they become feeble, less distinct, and that their expression changes, according as they are more distant from us; a man who is at the bottom of a well wishes to speak to persons who are at the top; but his voice will not reach their ears until it has received certain modifications, which depend upon the distance and the form of the tube through which it passes.

If a person remark these modifications with care, and endeavour to imitate them, he will produce acoustic illusions, which would be equally deceiving to the ear as the observation of objects through a magnifying glass is to the eye. The error will be complete if he employ those deceptions which are necessary to distract the attention.

These illusions will be numerous in proportion to the talents of the performer; but we must not imagine that a ventriloquist* produces vocal sounds, and articulates, differently from other people. His voice is formed in the ordinary manner; only he is capable of modifying, according to his pleasure, the volume, the expression, &c., of it; and with regard to the words that he pronounces without moving his lips, he takes care to choose those into which no labial consonants enter, otherwise he would be obliged to move his lips. This art is, in certain respects, for the ear what painting is for the eye.

Modifications of the voice by age.

Larynx of the fœtus and new-born infants.

The larynx is in proportion very small in the fœtus, and the new-born infant; its small volume forms a contrast with that of the os hyoides, with the tongue and other organs of deglutition, which are already much developed. Besides, it is round, and the thyroid cartilage forms no projection in the neck.

The lips of the glottis, the ventricles, the superior ligaments, are very short in proportion to what they become

* The word *Ventriloquist*, *Engastrimuthism*, and others which have the same signification, may have been employed in the infancy of the art, but ought not now to be admitted into scientific language.

afterwards; for the thyroid cartilage not being much developed, they consequently occupy a small space. The cartilages are flexible, and have not nearly the solidity which they possess afterwards.

The larynx at Puberty.

The larynx preserves these characters almost till puberty; at this period a general revolution takes place in the economy. The development of the genital organs determines a sudden increase in the nutrition of many of the organs, of which that of the voice is one.

The greatest activity of nutrition is first remarked in the muscles; afterwards, but more slowly, it is seen in the cartilages: the general form of the larynx is then modified; the thyroid cartilage becomes developed in its anterior part, it forms a projection in the neck, but greater in the male than in the female. From this circumstance results a considerable prolongation of the lips of the glottis, or thyro-arythenoid muscles; and this phenomenon is much more worthy of remark than the general increase of the glottis which happens at the same time.

Though these changes in the larynx are rapid they do not happen all at once; sometimes it is six or eight months before they terminate.

Larynx in the Adult.

After puberty the larynx does not suffer any other remarkable changes; its volume and the projection of the thyroid cartilage continue to increase, and become more strongly marked. The cartilages become partially ossified in manhood.

In old age the ossification of the cartilages continues, and becomes almost complete; the epiglottid gland diminishes considerably, and the internal muscles, but those particularly that form the lips of the glottis, diminish in volume, assume a colour less deep, and lose their elasticity: in a word they take the same modifications as the muscular system in general.

The production of voice, as it supposes the passage of air to and from the lungs to take place, cannot exist in the fœtus, plunged as it is in the *liquor amnii;* but the child is capable of producing very acute sounds at the instant of birth.

Vagitus or cry of children.

Vagitus is the name that is given to this voice, or cry of children, by which they express their wants and feelings. We must recollect that this is the object of the cry.

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

The pronunciation of children has very little resemblance to that of adults; but there is also a great difference between them. In children, the teeth have not yet quitted their *alveoli;* the tongue is comparatively very large; when the lips are closed they are larger than is necessary for covering anteriorly the gums; the nasal cavities are not much developed, &c. Voice and speech of children.

Children advance only by degrees, and in proportion as their organs of pronunciation approach those of the adult, to articulate exactly the different combinations of letters. They are not capable of forming appreciable sounds, or of singing, until long after they have acquired the faculty of speech. This sort of sounds is the voice properly so called, or acquired: they could not exist in the child were it deaf. They ought not to be considered as a modification of the vagitus.

Until the period of puberty, the larynx remains proportionably very small, as well as the lips of the glottis: the voice is also composed entirely of acute sounds. It is physically impossible that the larynx should produce grave ones.

At puberty, particularly in males, the voice undergoes a remarkable modification: it acquires in a few days, often all at once, a gravity, and a dull or deaf expression, that it was far from having before.

It sinks in general about an octave. The voice of a young man is said to *moult,* according to the common expression. In certain cases the voice is almost entirely lost for some weeks; it frequently contracts a marked hoarseness. Sometimes it happens that the young man produces involuntarily a very acute sound when he wishes to produce a grave one: it is then scarcely possible for him to produce appreciable sounds, or to sing true.

This state of things continues sometimes nearly a year, after which the voice becomes more clear, and remains so during life: but some individuals lose entirely, during the *moulting* of the voice, the faculty of singing; others, who having a fine and extensive voice before the *moulting,* have afterwards only a very ordinary one. Moulting of the voice.

The gravity that the voice acquires depends evidently upon the development of the larynx, and particularly on the prolongation of the lips of the glottis. As these parts cannot stretch backward, they come forward: it is also at this time that the larynx projects in the neck, and the *pomum Adami* appears. In the female, the lips of the glottis do not present at puberty this increase in breadth; the voice also generally remains acute.

Voice in old age.

The voice generally preserves the same characters until after adult age; at least, the modifications that it undergoes in the interval, are but inconsiderable, and affect principally the expression, and the volume. Towards the beginning of old age, the voice changes anew, its expression alters, and its extent diminishes: singing, is more difficult, the sounds become noisy, and their production painful and fatiguing. The organs of pronunciation being changed by the effect of age, the teeth become shorter, and frequently being lost, the pronunciation is sensibly changed. All these phenomena are more noted in confirmed old age. The voice is weak, shaking, and broken; singing has the same characters, which depend on impaired muscular contraction. Speech also undergoes remarkable modifications; the slowness of the motions of the tongue, the want of teeth, the lips proportionally longer, &c. necessarily influence the pronunciation.

Relations of Hearing and Voice.

Relations of hearing and voice.

We have already given an account of the relation between the voice and the hearing: it is such, that a child born deaf is necessarily dumb also; that a person who has a false ear, has consequently a false voice; that a person who hears badly is inclined to speak high, &c.

We ought not to believe, however, that the larynx of persons born deaf is incapable of producing the voice; we have already said that it produces the cry. We succeed, by different methods, to make it produce the voice; even persons deaf and dumb from birth have been brought to speak so as to sustain a conversation; but their voice is hoarse, dull, unequal: different inflections happen very unequally, and without any motive.

I do not think that a person born deaf and dumb has ever been brought to learn to sing.

There are examples of persons who have acquired hearing at an age when they could give an account of their sensations; in all of them the voice was developed a short time after they could hear with facility.

The *Memoires de l'Academie des Sciences*, of the year 1703, present an example of this kind, which happened to a young man at *Chartres*, twenty-four years old, "who, to the great astonishment of all the town, began speaking all of a sudden. He told that, three or four months before, he had heard the sound of bells, and had been very much surprised with this new and unknown sensation: there was afterwards a sort of water that passed out of his left ear, and he heard perfectly with both ears. He continued for these three or four months hearing, without saying any thing of it, repeating to himself the words that he heard, exercising himself in pronunciation, and in the ideas attached to words. At last he thought himself in a state to break silence, and he maintained that he could speak, though it was still but very imperfectly. Immediately he was interrogated by able theologians," &c.

It is unfortunate for science that this young man was not observed by physicians: his history might have been more interesting.

A fact of the same kind happened at Paris some years since. A young person, deaf and dumb from birth, about fifteen years of age, was cured of his deafness by *Doctor Itard*, by means of injections thrown into the tympanum through an opening made in the *membrana tympani*. The young man heard first the sound of the neighbouring bells; at that instant he felt a very lively emotion; he had even head-ache, vertigo, and dizziness. The next day he heard the sound of the small bell in the room; twenty days afterwards he could hear the voice of persons speaking. He was then extremely delighted, nor could he be satisfied with hearing people speak. "His eyes," says Professor Percy, "seemed to search for the words even on our lips." His voice was soon developed. He formed only vague sounds at first; some time afterwards he could stutter some words, but he pronounced them badly like children. It was some time before he could pronounce compound words, and those containing a number of consonants. They caused him to hear a *hurdy-gurdy* (*vielle organiscé*,) without preparing him for it; he was then observed to tremble, turn pale, and seemed on the point of falling into a syncope; he next showed all the transports occasioned by a lively and unknown pleasure; his cheeks became red, his eyes sparkling, his respiration hasty, and his pulse rapid, indicating a sort of delirium, an intoxication of happiness.

There would have been, no doubt, many other surprising phenomena seen in this young man, if a disease had not suddenly carried him away from the medical philosophers who observed him.

Of the Sounds independent of the Voice.

Sounds which are not formed by the larynx.

Independent of the voice, man can produce at pleasure a great number of sounds, inappreciable, and even appreciable, such as the noise of spitting or blowing one's nose; that by which we call a horse; that which is like the sound of drawing a cork: such also as the whistling through the teeth or the lips, whether it is formed by inspiration or expiration; and a great many other noises which result from the motion of the different parts of the mouth, and from the manner in which the air enters and leaves it.

It is not easy to account for the mechanism of the production of these different sounds, particularly those that are appreciable, as in the action of whistling; we have nothing on this point but approximations.

OF ATTITUDES AND MOTIONS.

Attitudes and Motions.

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

The explanation of the motions and attitudes of man consists in the application of the laws of mechanics to the organs by which they are executed.

Our attitudes and motions being so various, were we determined to explain them all, we might find an application for almost all the laws of mechanics.

Nobody has yet undertaken this labour in a satisfactory manner; only the most frequent attitudes and motions have been explained, and by an application of the most simple mechanical principles.

Mechanical Principles necessary for understanding Motions and Attitudes.

The line along which the gravity of a body is exerted is called the *vertical.*

In every position of a body the vertical passes through different points; but there is one in which all the directions of this force cross each other; this point is called the *centre of gravity.* Of the centre of gravity.

The condition of the equilibrium of a heavy body, placed on a horizontal plane, is, that the perpendicular which descends from the centre of gravity upon the horizontal plane falls between the points upon which the body rests. Equilibrium.

The equilibrium of a heavy body upon a horizontal plane is so much more stable as the centre of gravity is nearer the plane, and as the surface upon which it rests is of greater extent.

The base of support is the space determined between the points upon which the body rests on the plane. Of two hollow columns, formed of an equal quantity of matter, and of the same height, that which presents the greatest cavity will be the strongest. Base of support.

Of two columns of the same diameter, but of a different height, the highest will be the weakest. Resistance of columns.

The greatest weight that can be borne by a spring that suffers small flexions, is proportional to the square of the number of flexions *plus one:* so that, if the spring present three bendings, it will support a weight sixteen times greater than if it had not any. Resistance of curved springs.

OF LEVERS.

The definition of a lever is, an *inflexible line,* which turns upon a fixed point. Of Levers.

We distinguish in a lever the point of support, the point where the power acts, the point of resistance, or simply the point of support, the power, and resistance.

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

Lever of the first 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.

Second kind.

The lever of the second kind is that in which the resistance is between the power and the point of support, and in which the points of support and the power each occupy an extremity.

Lever of the third kind.

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

Arms of the Lever.

We distinguish also in a lever the arm of the power, and that of the resistance. The first comprehends that part of the lever which extends between the point of support and the power; the second is that portion of the lever that extends from the point of support to the resistance.

When, in the lever of the first kind, the point of support is exactly in the middle, the lever is said to have its arms equal; when the point of support is nearer the power, or the resistance, we say that the arms of the lever are unequal.

Influence of the length of the Lever.

The length of the arm of the lever gives more or less advantage to the power, or to the resistance. If, for example, the arm of the power is longer than that of the resistance, the advantage is for the power, in the proportion of the length of its arm to that of the arm of resistance; in such a manner, that if the first of these arms be double, or treble the length of the second, it will be sufficient for the power to be half, or a third part as great as the resistance, for the two forces to be equal.

In the lever of the second sort, the arm of the power is necessarily longer than that of the resistance, since it is between the power and the point of support, whilst the power is at one extremity. This kind of lever is always advantageous for the power.

The contrary takes place with the lever of the third sort; because in this lever the power is placed between the resistance and the point of support, whilst the resistance is at an extremity. The lever of the first kind is most favourable for an equilibrium; the lever of the second sort is most favourable for overcoming resistance; and that of the third kind is most favourable to extensive and rapid motions.

The direction in which the power is inserted into the lever is of importance to be remarked. The effect of the power is so much more considerable as its direction approaches towards a perpendicular to that of the lever.—When this last condition is complete, the whole of the force is employed in surmounting the resistance; whilst, in oblique directions, a part of this force tends to move the lever in its proper direction, and this portion of the power is destroyed by the resistance of the point of support. Insertion of the power into the Lever.

Moving Power.

We call *inertia* that general property of bodies, by virtue of which they continue in their state of motion or repose, whilst they are not acted upon by any foreign cause. Inertia.

The power which produces motion must be measured by the quantity of motion produced. This quantity is estimated in multiplying the mass by the acquired velocity.

This velocity may be acquired in two different ways: by the continued action of a power, as that of gravity; or by the effect of a power which produces, instantaneously, a given velocity.

We may easily conclude, from what has been said, that every effort exerted upon a body at liberty will produce motion. The direction of this motion, the velocity acquired, and the space passed by the body, will depend on its mass, or on the effort exerted upon it, and upon the causes which act upon it during its motion. Causes which influence motion.

Thus a body projected by the hand acquires, instantaneously, a velocity so much greater as the effort is greater and the mass less: the constant action of gravity modifies this velocity, and the direction of the motion, which ceases when the body falls to the ground. Motion is also lessened by the resistance of the air, the force of which increases with the velocity of the body, with the extent of the surface which is continually opposed to the air, and with the specific lightness of the body.

Friction is that resistance which we are obliged to overcome in making one body slide upon another. Friction.

Adhesion is that power which unites two polished bodies laid one upon another. The force of adhesion is measured by the effort we exert perpendicularly to the surface of contact, in order to separate the two bodies. Adhesion.

The more the surfaces are polished the adhesion is the greater, and the friction less: again, if the object is only to make one body slide upon another, it will be a great advantage to polish the surfaces, or to interpose a liquid.

OF THE BONES.

The bones, which determine the general form and dimensions of the body, have, on account of their physical properties, a very important use in its different positions and motions: they form the different levers which the animal machine presents, and which transfer the weight of the body along the surface of the ground.

As levers, they are employed sometimes as the first sort; sometimes as the second or third. When an equilibrium is necessary, the lever of the first sort is almost always employed; if there is a considerable resistance to overcome, they then represent a lever of the second sort. In other motions they are employed as levers of the third sort, which, as we know, are disadvantageous to the power, but favourable to extensive and rapid motions.—Most of the projections and prominences of the bones are of use in changing the direction of the tendons, and in causing their insertion nearer the perpendicular. As a means of transmission of weight, the bones represent columns placed on each other, almost always hollow, which very much increases the general resistance which the skeleton presents, as well as that of each bone in particular.

Form of the Bones.

Form of the bones.

The bones are distinguished into short, flat, and long. The short bones are found in the parts where little mobility, and great strength are necessary, as in the feet, and the vertebral column.

The principal use of the flat bones is to form the sides of cavities; they also contribute greatly to the motions and attitudes by the extent of the surface they present for the insertion of the muscles.

The long bones are principally intended for locomotion: they are found only in the members. The form of body and extremities of them deserve attention. The body of these bones is the part which presents the least volume; it is generally rounded; the extremities, on the contrary, are always more or less voluminous.

The dispositions of the body of the bones concur in the elegance of form of the members; the volume of the articulating extremities, besides having the same use, insures solidity to the articulations, and diminishes the obliquity of the insertion of the tendons upon the bones.

Structure of the bones.

The short bones are almost entirely of a spongy substance, whence it happens that they present a considerable surface without being too heavy. The extremities of the long bones are the same; but their body presents a compact substance in great quantity, which gives it a great power of resistance, this being very necessary in these bones, as it is upon the middle of them that the efforts they sustain rest.

The spongy tissue of the short bones, and the extremities of the long ones, are filled by the medullary juice.

The cavity of the long bones is filled with the marrow.

Articulations of the Bones.

Different sorts of articulations.

They are distinguished into those that do, and those that do not allow of motion.

The first division presents subdivisions founded upon the form of the articulating surfaces.

The second also presents subdivisions, founded upon the articulating surfaces, and upon the kind of movement that the articulations permit.

Moveable articulations.

In the moveable articulations the bones never touch one another immediately; there is always between them a substance which is elastic, and differently disposed according to the articulations, and intended to support easily the strongest pressure, to lessen shocks, and favour motions. Sometimes this substance is *single*, 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 particular bed upon *each* articular surface: as is seen in articulations of *contiguity*. In this case the substance is cartilaginous.

Cartilages and fibro-cartilages.

It is said, that the substance which, in this kind of articulations covers the bones, is formed of parallel fibres, perpendicular to the surface which they cover: this opinion seems to require new researches. The cartilages have more the appearance of being formed of one homogeneous stratum.

Synovia.

Articulations thus disposed present the most favourable dispositions for sliding motions. The surfaces in contact are finely polished, and a particular liquid, the synovia, continually moistens them. For the same reasons the adhesion is very great, and this circumstance adds to the strength of the articulation by contributing to prevent displacements.

Inter-articular fibro-cartilages.

In certain moveable articulations there are between the articulating surfaces fibro-cartilaginous substances which do not adhere to those surfaces. The use which has been assigned to them is to form a sort of cushions, which giving way to pressure, recover again their form, and protect the articular surfaces to which they correspond.

They are said to be found so placed in articulations which support the greatest pressure. We think that this opinion is not sufficiently founded. Indeed the articulations of the hip, and particularly those of the foot, which supports the greatest efforts, do not present them. Is their use not rather to favour the extent of motions, and to prevent displacements? Around, and sometimes in the interior of articulations, there are fibrous bodies found,

Ligaments

called *ligaments*, which have for a double use the maintaining the bones in their respective situations, and limiting their motions on one another.

Attitudes of Man.

Erect posture.

Let us examine man in his different positions, and first in his most ordinary position, that is, upon his feet. We see, in the first place, that the head intimately united with the atlas, forms a lever of the first kind, of which the point of support is in the articulation of the lateral masses of the atlas and of the axis, whilst 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 the occiput than the anterior part of the face, the head tends by its weight to fall forward; but it is retained in equilibrium by the contraction of the muscles attached to its posterior part. It is then the vertebral column which supports the head, and which transmits the weight of it to its inferior extremity. The superior extremities, the soft parts of the neck, and of the thorax, the greater part of those contained in the abdominal cavity, are supported, mediately or immediately, upon the vertebral column.

On account of the weight of these parts it was necessary that the vertebral column should present great solidity. In fact, the vertebrae, the intervertebral fibro-cartilages, the different ligaments which unite them, form a whole of great solidity. If we, then, reflect that the vertebral column is formed of superincumbent cylindric portions; that it has the form of a pyramid, the base of which rests on the sacrum; that it presents three curves in opposite directions, which give it sixteen times more resistance than if it had none, we will then have an idea of the resistance which the vertebral column offers. We also see it support not only the weight of the organs, but also very heavy burdens.

The weight of the organs which the vertebral column sustains, being felt particularly upon its anterior part, muscles placed upon the posterior part, resist the tendency which it has to bend forward. In this circumstance every vertebra, and the parts attached to it, represent a lever of the first kind, of which the point of support is in the fibro-cartilage which sustains the vertebrae; the power in the parts which draw it forward; and the resistance in the muscles which are attached to its spinous and transverse processes.

The whole of the vertebral column represents a lever of the third sort, the point of support of which is in the articulation of the fifth vertebra of the loins, with the os sacrum, the power of which is in the parts which tend to draw the column forward, and the resistance in the posterior muscles. As the power acts principally upon the inferior part of the lever, nature has there placed the strongest muscles; the pyramid which the vertebral column represents has there the greatest thickness, and the vertebral processes are more marked and horizontal: fatigue is also felt there when we remain long in a standing position.

The muscular power will act so much more powerfully to preserve the equilibrium necessary in a standing position, as the spinous processes are longer, and nearer a horizontal direction.

The weight of the vertebral column, with the parts which rest on it, is transmitted directly to the pelvis, which, resting upon the thighs, represents a lever of the first sort, of which the point of support is in the *ilio-femoral* articulations; the power and resistance are placed before or behind.

The pelvis supports also part of the weight of the abdominal viscera.

The sacrum supports the vertebral column, and acting like a wedge, it transmits equally to the thighs, by means of the *ossa ilii*, the weight that it supports. The pelvis is really in equilibrium upon the heads of the two thighs; but this equilibrium results from a great number of efforts combined.

On one hand, the abdominal viscera pressing upon the pelvis, inclined forward, tend to depress the pubis; on the other, the vertebral column tends by its weight to give the pelvis a swinging motion backwards.

The weight of the vertebral column being much greater than that of the abdominal, it seems necessary that, to establish the equilibrium, muscular powers would be sufficient, which, commencing in the thighs, should be attached to the pubis, and there, by their proper contraction, counterbalance the excess of weight of the vertebral column.

These muscles, in fact, exist; but they do not act principally to determine the equilibrium of the pelvis upon the thighs; because the pelvis, very far from swinging backwards, would rather incline forwards, as the muscles which resist the inclination of the vertebral column forward, having their fixed point upon the pelvis, make a considerable effort to draw it upwards. It is, then, those muscles which, leaving the thigh, go to the posterior part of the pelvis, which prevent it from rising, and which are the principal agents in the equilibrium of the pelvis upon the thighs: Nature has, therefore, made them very numerous and strong.

The articulation of the thigh with the *os ilii*, is nearer the pelvis than the sacrum; whence it results that the posterior muscles act by a longer arm of the lever, which is a favourable circumstance for their action.

In the usual state of standing, the thighs transmit directly the weight of the trunk to the tibia.

They are very fit for this use, on account of their articulation with the *os ilii.*

The neck of the thigh, besides its use in motion, is useful in a standing position, by directing the head of the thigh upward and inward in an oblique direction; and hence it results, that it supports the vertical pressure of the pelvis, and resists the separation of the *ossa ilium* which the sacrum tends to produce.

The thigh transmits the weight of the body to the tibia; but, by the manner in which the pelvis presses upon its inferior extremity has a tendency forward, whilst the contrary takes place with the superior extremity: whence it follows, that, to keep it in equilibrium upon the tibia, there must be strong muscles opposed to this motion. These muscles are the *rectus anterior* and the *triceps femoris,* the action of which 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, concur also in the maintenance of this equilibrium.

The tibia transmits the weight of the body to the foot; the fibula does not aid in it. But, in order that the former of these bones perform this office well, there must be muscles opposed to the direction in which its superior extremity inclines forwards. The *gemelli* and *soleus* principally perform this office; all the other muscles of the posterior part of the leg also aid in it.

The foot supports the whole weight of the body; its form and structure correspond with this use. The sole of the foot is very broad, which contributes to the solidity of the standing position. The skin, and the epidermis of this part, are very thick. Above the skin is a fatty layer of considerable thickness, particularly upon those parts where the foot presses on the ground. This fat forms a sort of elastic cushion, very fit to deaden, or diminish, the effects of pressure occasioned by the weight of the body.

The foot does not touch the ground on the whole extent of its inferior aspect; the heel, the external edge, the part which corresponds to the anterior extremity of the metatarsal bones, the extremity, or pulps of the toes, are the parts which commonly touch the ground, and transmit to it the weight of the body: there are also in each of these points considerable bundles of fat, intended to prevent the inconvenience of so strong a pressure. That which is placed immediately under the *head* of the *calcaneum* is very remarkable; it is smooth upon its superior face, and merely contiguous to the bone; it is, besides, distinct from the rest of the fat of the heel. The other bundles, or cushions of fat are in smaller quantity; but they are disposed in a manner analogous to that of the heel.

The tibia transmits the weight of the body upon the astragalus, which, in its turn, transmits it to the other bones of the foot; but the *calcaneum* receives the greatest part of it, the remainder being divided amongst the other parts of the foot which rest on the ground.

The general manner of this transmission is as follows:—

The effort sustained by the astragalus is transmitted, 1st, to the heel bone; 2dly, to the *os scaphoides*. The heel bone being placed immediately under the astragalus, receives the greater part of the pressure; it transmits it partly to the ground and partly to the *os cuboides*. This last bone, and the *os scaphoides*, by means of the *ossa cuneiformia*, press, in their turn, on the metatarsal bones, which, resting on the ground, transmit to it nearly all the pressure they support: the surplus goes to the toes, and finishes by terminating in the *basis of support*. This mode of transmission supposes the foot to touch the ground in the whole extent of the sole.

As the pressure of the tibia is felt particularly in the internal part of the foot, this tends always to spread outwards. The *fibula* is intended to preserve the foot in the erect position which is necessary for standing.

We have seen that the muscles that prevent the head from falling forward, in standing, have their fixed point in the neck; that those which perform the same office, with regard to the vertebral column, have theirs in the pelvis; that those which preserve the pelvis in equilibrium are attached to the thighs, or to the bones of the leg; that those which prevent the thighs from falling backwards, are inserted into the tibia; and, lastly, that those which preserve the tibia in their vertical position, have their fixed point in the feet. The feet, then, must support all the efforts which are necessary to a standing position; the feet must present a resistance equal to the effort which they have to support. But the feet have not, by themselves, any other resistance than that of their weight; all that they present is communicated to them by the weight of the body which they support; so that the same cause that tends to make us fall, is the same which preserves us firm in a standing position.

The space between the feet, added to that which they cover, forms the base of support. The condition of equilibrium for standing erect is, that the vertical, descending from the centre of gravity, shall fall upon one of the points of the base of support. The standing position will be so much more firm as this base is broader; in this respect, the size of the feet is far from being indifferent.

It is seen, by observation, that a standing position is as firm as possible, when the two feet directed forwards on two parallel lines, are separated by a space equal to the length of one of them. If the base of support is enlarged in a lateral direction, by separating the feet, the standing becomes more firm in this direction; but it is less so from behind and before. The contrary takes place when one foot is placed before the other.

The more the base of support is diminished, the less firm we stand, and the more efforts of the muscles it requires to sustain us in our position. This happens when we are raised on our toes. In this case, the feet touch the ground only in the space between the anterior extremity of the metatarsal bone, and the extremity of the toes; —a mode of standing which is fatiguing, and cannot be long supported. Some persons, such as dancers, can raise themselves upon the extremities of the toes; we may conceive that this position is still more difficult. To conclude, whatever be the part of the foot which touches the ground, it is always comprehended amongst the four parts that we mentioned at the beginning of this article, and we cannot be ignorant of the bundles of *fatty cellular tissue* which correspond to them.

Standing becomes very painful, or even impossible, if the feet rest upon a plane which is very narrow: for example, a tight rope.

In general, it may be understood that every cause which narrows the base of support will diminish the solidity of the standing position, in proportion as this base is diminished, as may be ascertained in examining individuals who have lost their toes by frost, or the anterior part of the foot by partial amputation; those who have one or two wooden legs, or those who use stilts. In this last case standing is rendered still more difficult by the distance from the centre of gravity being greater. Standing upon two feet may take place in a great number of different positions of the body besides the usual mode. The trunk may be inclined forward, backward, or laterally; the lower extremities may be bent in various positions. If what we have said of standing in an upright position be well understood, it will be easy to explain the attitudes here in question.

Standing on one foot.

In certain circumstances we stand on one foot. This attitude is necessarily fatiguing; it requires a strong and continued action of the muscles which surround the articulation of the hip, whence results the equilibrium of the pelvis upon one thigh; and as the body, and consequently the pelvis, tend to incline towards the side of the leg which is not supported on the ground, the great, small, and middle glutei muscles, the tensor of the facia lata, the gemelli, pyramidalis, obturators, and quadratus, must be so contracted as to support the body.

We have reason to remark here the use of the neck of the thigh bone, and the process called the *great trochanter;* they evidently render much more oblique the insertion of the above-mentioned muscles, and on this account there is much less loss in the force of their contraction.

It is not necessary to add, that in standing on one foot the base of support is represented by the surface which the foot covers, and therefore it is always less solid than standing on both feet, whatever may be their position. It will become still more difficult and tottering, if, in place of resting on the whole extent of the foot, we rest only on one point of it. It is scarcely possible to preserve such an attitude more than a few moments.

Kneeling.

Kneeling posture.

In this position the base of support seems to be very large; and as the centre of gravity is lowered, we might suppose that it is much more solid than standing upon the two feet: but the breadth of the base which supports the weight of the body is very far from being measured by all the surface of the two limbs which touch the ground.

The patella almost alone transmits the pressure to the ground; besides, the skin which covers it being strongly compressed, and not being supported by elastic fatty substance, as is seen in the skin of the foot, it would be very soon hurt were it to remain long in this position. To diminish the effects of this pressure we place a cushion under the patella, when we intend to remain long in a kneeling position, or we transmit to the ground a part of the weight of the body by some other support.

It is with the same intention, that is, to spread over a greater surface the pressure caused by the weight of the body, that we bend the thighs backwards, and rest them on the legs and heels; the position then becomes very solid and easy, because the base of support is then large, and the centre of gravity very near.

Sitting.

We may sit in different postures: upon the ground, the legs extended forward; upon a low seat, upon a common seat, with the feet touching the ground; upon a high seat, the feet off the ground, with the back either supported or not supported. Sitting posture.

In every sitting position in which the back is not supported, and the feet resting on the ground, the weight of the trunk is transmitted to the ground by the pelvis, the breadth of which below is larger in man than in any of the animals.

The base of support of the trunk becomes distinct from that of the lower limbs; it is represented by the extent which the hips cover upon the resisting plane which supports them. The larger they are, and the better supplied with fat, the sitting position will be the more solid.

When the back is not supported in the sitting attitude, it causes the permanent contraction of the posterior muscles of the trunk which prevent it falling forward; it is therefore fatiguing, as we may find on remaining long seated on a stool.

The same thing does not happen when the back is supported by a solid body, as happens when we sit on a chair: then none of the muscles are required to act except those that sustain the head, and they are the only ones that suffer any fatigue. Long chairs are intended to prevent this inconvenience, because they support both the back and the head. In whatever manner we are seated we can continue this position a long time; 1st, because only the contraction of a small number of muscles is necessary; 2dly, because the base of support is large, and the centre of gravity is near; 3dly, because the hips, on account of the thickness of skin, and the quantity of fat which they contain, are able, without any inconvenience, to support a long-continued and heavy pressure.

Of the Recumbent Posture.

Recumbent posture.

Lying is the only position of the body which requires no muscular exertion; this is also the attitude of repose, and that of weak or sickly persons who labour under great deficiency of strength; it is also that which can be preserved the longest. 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, though distributed over a great space, and having little action on each particular point, is sufficient to produce inconvenience at first, and afterwards pain. And if the position is long continued, as happens in certain diseases, the skin becomes excoriated and gangrenous, particularly in the points which support the greatest pressure, as the posterior surface of the pelvis, the great trochanters, &c. To avoid this inconvenience, we procure soft and elastic beds, which permit a more equal distribution of pressure upon all the different points corresponding to the base of support.

Of Motions.

We observe two sorts of motion: the first is intended to change reciprocally the position of the different parts of the body, the second to change the position of the body relatively to the surface; the first sort are called partial, the second locomotive.

Of Partial Motions.

Partial motions.

The greater number of partial motions are an inherent part of the different functions; many of them have been already described, the rest will be so in their turn.

Here we treat only of those that can be separated from the history of the functions. We will speak in succession of those of the head, of the face, those of the trunk, those of the superior limbs, and lastly, of those of the inferior extremities.

Partial Motions of the Face.

It is easy to observe that motions have two distinct objects; the first to contribute to the sensations of sight, of smell, and of taste, as in the apprehension of food, in mastication, deglutition, voice and speech; the second in expressing the intellectual actions and passions.

Partial motions of the Face.

Independently of the motions of the face which contribute to vision, smell, taste, to the voice and speech, &c., and of which, indeed, we have already spoken, and of those which serve for taking our food, for mastication, deglutition, &c., of which we shall speak in their place, the muscles of the face determine some motions, the use of which is to express certain intellectual acts, the different dispositions of the mind, the instinctive desires and the passions. Pleasure, pain, joy, sorrow, desires and fear, anger, love, &c., have each an expression of the face by which it is characterized. However, the painful and sorrowful affections, violent desires, are generally marked by a contraction of the visage: the eyebrows are knitted, the mouth contracted and its sides lowered; on the contrary, in the soft and gay affections, in agreeable sensations, satisfied desires, the countenance expands, the eyebrows are raised, the eyelids are separated, the angles of the mouth are drawn upward and outward, which causes smiling. Those persons in whom the different expressions are the most marked, or who in ordinary language, are said to have a physiognomy, are endowed with a lively sensibility. The contrary generally takes place with persons whose visage is incapable of strong expression. When a certain disposition of the mind, or a passion continues for a certain time, the muscles, which are habitually contracted to express it, acquire a greater volume, and assume a manifest preponderance over the other muscles of the face: the physiognomy then preserves the expression of the passion, even when it is not felt, or long after it has ceased. The consideration of his physiognomy is thus an excellent means by which to judge of the character or ordinary passions of an individual.

Physiognomy.

The colour, or change of colour of the skin of the face, is likewise a strong means of expression of the mind and

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of the passions; we will treat of it in the article *Capillary Circulation.*

Motions of the Head upon the Vertebral Column.

Partial motions of the head.

The head may be inclined forward, backward, or laterally; it can also turn to the right or to the left. The motions by which the head is inclined, forward, backward, or laterally, provided they are not extensive, take place in the articulation of the head with the first *cervical vertebra;* but if their extent is considerable, all the *vertebrae* of the neck participate in them.

The rotatory motions take place essentially in the articulation of the atlas and the axis, evidently intended for this use. These different motions which are frequently combined, are determined by the simultaneous or successive contractions of the muscles, which go from the neck and breast to the head.

We easily see that the motions of the head are favourable to sight, smelling, and hearing; they are also useful to the production of the different tones of the voice, in permitting the prolongation, or shortening, of the *trachea,* of the vocal tube, &c. These motions serve also as a means of expressing the intentions of the mind; approbation, consent, refusal, are marked by certain motions of the head upon the neck; some passions also occasion particular attitudes of the head.

Motions of the Trunk.

In this article we will speak only of those motions which are peculiar to the vertebral column; those that are peculiar to the chest, the abdomen, and the pelvis, will be treated of elsewhere.

Flexion, extension, lateral inclination, circumduction, and rotation, such are the motions that the vertebral column performs as a whole, and such also does every region and even every vertebra perform in particular.

Partial motions of the trunk.

These different motions take place in the intervertebral fibro-cartilage; they are so much more easy and extensive as these fibro-cartilages are thicker and broader: for which reason the motion of the lumbar and cervical portions of the vertebral column are evidently more free and considerable than those of the dorsal portion. It is well known that the cervical fibro-cartilages, and particularly the lumbar, are proportionally thicker than the dorsal.

In the motions of flexion, forward, backward, or laterally, the fibro-cartilages are pressed down in the direction of the flexion, and prolonged on the opposite side. The thickest part is that which admits the most considerable compression. This is one of the reasons why the flexion forwards is much more extensive than any other motion of the vertebral column.

In rotation, the whole of these intervertebral bodies must support a prolongation in the same direction as the plates of which they are composed. The centre of these bodies presents a soft matter, almost fluid; the circumference alone offers a considerable resistance, and, nevertheless, in those motions in which the vertebrae approach each other, this circumference gives way sufficiently to form a sort of cushion between the two bones. The disposition of the articular surfaces of the vertebrae is one of the circumstances which has most influence upon the extent and the mode of the reciprocal motions of the vertebrae.

When we regard the vertebral column in the whole of its motions, it represents a lever of the third kind, of which the point of support is in the articulation of the fifth lumbar vertebra with the sacrum; the power is in the muscles which are inserted into the vertebra on the sides; and the resistance in the weight of the head, the soft parts of the neck, of the chest, and part of the abdomen. On the contrary, each vertebra, taken separately, represents a lever of the first kind, of which the point of support is in the middle, upon the vertebra placed immediately below. The power and the resistance are alternately before or behind, or on the right or left, 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 then appear to enjoy an extent, which they are very far from having.

The motions of the vertebral column are intended frequently to favour those of the superior and inferior extremities, and to render less fatiguing, and more supportable, the different attitudes and positions of the whole body.

Motions of the Superior Extremities.

Motions of the Superior Extremities.

The superior extremities, being the principal agents by which we impress directly, or indirectly, upon those bodies which surround us those changes which we find suitable, ought to possess an extreme mobility joined to great solidity. In fact, we observe, in these members, many bones are of a considerable length that are very slender; the short bones are not large: both are but light; the articulating surfaces are of small dimensions; the muscles are very numerous, and their fibres often very long. The bones represent, almost always, levers of the third sort, which are favourable, as we have already said, to extensive and rapid motions. Whether we consider the superior extremities in their *motions of totality*, relatively to the trunk, or in their partial motions, we see that they unite in a superior degree, extent, rapidity, and variety of motion.

The solidity of these limbs is not less worthy of remark. In a great many cases they have to support considerable efforts, as when we support ourselves on a stick, when we fall forwards, and the hands receive the shock of the fall.

We cannot possibly enter into the details of this wonderful mechanism; we refer to the *Descriptive Anatomy of Bichât*, whose genius has been successfully exerted in the description of animal mechanism.

The superior extremities are essentially useful in the exercise of the touch, of which the hand is the principal organ; they assist in the action of the other senses in bringing near or removing bodies, or in placing them so as to be acted on with the greatest ease. Their motions express powerfully the instinctive and intellectual operations.

Gestures form a real language, which is susceptible of acquiring great perfection when it becomes very necessary, as with those who are deaf and dumb. In those cases, gestures not only paint the feelings, the wants, the passions, but they express even the finest shades of thought. The superior limbs are often useful in the different attitudes of the body. In certain cases a portion of its weight is transmitted by them to the ground, and, consequently, they increase the base of support: this takes place when we rest on a staff: when kneeling, we place our hands on the ground; when seated on a horizontal plane, we support ourselves on our elbows, &c.

They may also render the position of standing more solid by being directed to the side opposite to that towards which the body inclines to fall by its weight. We will see immediately that they are not without their use in the different modes of progression.

Motions of the Inferior Extremities.

Though the analogy of structure between the superior and inferior extremities is manifest, it is not less evident that nature has done much less for the quickness and variety of the motions of the former, than for the solidity and extent of those of the latter; this disposition was very necessary, for the lower extremities rarely move without supporting the weight of the body, and they are the principal agents of our locomotion. Motions of the Inferior Extremities.

Nevertheless, when we impress any modifications upon exterior bodies by the inferior extremities, they move independently of the trunk: as when we change the form of a body in pressing it with the foot, or when we displace it by striking it with the foot; when we feel with the foot to determine the resistance of the ground upon which we walk, &c., we see clearly that these different motions do not necessarily occasion that of the trunk. We will not describe here particularly the different motions, either general or partial, which are effected by the members; we will treat only, in an abridged manner, of the different modes of locomotion; that is, of the different modes by which the body is transported from one part to another, which are *walking*, *running*, *leaping*, and *swimming*.

Of Locomotion.

The action of walking is not performed always in the same manner. We walk forwards, backwards, sideways, and in intermediate directions; we ascend, or descend, upon a solid or moveable surface; walking also differs as to the length and quickness of the steps. Of Walking.

Whatever is the mode of walking, it is necessarily composed of a succession of steps; so that a description of walking is only the description of a succession of steps.— The step, with its principal modifications, is what is necessary to be known.

Suppose a man standing, his two feet placed together, and beginning to walk upon a horizontal plane, with a step of an ordinary quickness and length, he must bend one of the thighs upon the pelvis, and the leg upon the thigh, in order, by the shortening of the limb, to remove the foot from the ground. The flexion of the thigh causes the movement of the whole limb forwards: the limb next rests itself on the ground; the heel touches first, and then in succession the whole lower surface of the foot. Whilst this motion is being performed, the pelvis suffers a horizontal rotatory motion upon the top of the thigh of the limb that remains at rest. The result of this rotatory motion upon the head of the thigh is—1st, to carry forward the whole of the limb detached from the ground; 2d, to carry forward also the side of the body corresponding to the moving limb, whilst the side corresponding to the immovable limb remains behind.

These two effects are scarcely perceivable in short steps; they are strongly marked in ordinary steps, but still more so in those that are long: there is not yet any progression, the base of support only is modified. To finish the step, the limb that remained behind must advance, place itself on the same line, or pass that which went before. For this purpose the foot which is behind is detached from the ground, successively from the heel to the toe by a motion of rotation, 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 only by these latter. From this motion arises a prolongation of the limb, the effect of which is to carry forward the corresponding side of the trunk, and to determine the rotation of the pelvis upon the head of the thigh of the limb that was first moved. This motion once produced, the limb bends, the knee is directed forward, the foot detached from the ground; the whole limb then performs the same motions that were performed by that of the opposite side.

By the succession of these motions of the inferior limbs and of the trunk, walking is produced, in which we see that the heads of the thighs are by turns the fixed points upon which the pelvis turns as upon a pivot, in describing arcs of a circle so much larger in proportion as the steps are long.

Walking forward.

In order that walking may be in a right line, the radii of the circle described by the pelvis, and the extension of the members when carried forward must (on each side) be equal: without this condition the body will deviate from a right line, and be carried from the side opposite to the limb whose motions are of the greatest extent; as it is difficult to make the two limbs perform successively motions of the same extent, we always tend to deviate from a right line, and would so deviate effectually unless we were enabled to correct it by the eye. We may be easily convinced of this in walking some time with our eyes shut.

We have described the mechanism of walking forward; it will not be difficult to have an idea of walking backward or sideways.

Walking backward.

When the step is turned backward, one of the thighs is bent upon the pelvis, while the leg is bent upon the thigh; the extension of the thigh upon the pelvis succeeds, and the whole of the limb is carried back; the leg is afterwards extended upon the thigh, the point of the foot touches the ground, and afterwards its whole lower surface. The instant that the foot which went backward touches the ground, that which remains before is raised upon the toe; the corresponding limb is prolonged; the pelvis, pushed back, has a rotatory motion upon the thigh of the limb directed backwards; the limb which is before quits the ground entirely, and is carried back of itself in order to furnish a new fixed point for another rotatory motion upon the pelvis, which the opposite limb will produce.

When we wish to walk sideways, we at first bend slightly one of the thighs upon the pelvis, in order to detach the foot from the ground; we next carry the whole limb in a lateral direction, and afterwards place it on the ground; we then place the other limb beside it, and so on for the rest. In this case there is no rotation of the pelvis upon the thighs.

Walking on an ascending plane.

We know that the fatigue is much greater in walking upon an ascending plane: in this kind of progression the flexion of the limb carried first forward is much greater, and that which remains behind must not only perform the rotatory motion upon the pelvis, but it must raise the whole weight of the body, in order to carry it forward to the limb which is before.

The contraction of the anterior muscles of the thigh carried forward is the principal cause of the transport of the weight of the body. These muscles also become much fatigued in the action of mounting a stair, or any other ascending plane.

Walking on a descending plane.

For the contrary reason, walking upon a descending plane is also more painful than on a horizontal one. In this case the posterior muscles of the trunk must be forcibly contracted to prevent the body falling forward.

The modes of progression which we have thus rapidly described, require, necessarily, an equal action of all the articulations of the inferior extremities; the least difficulty in the play of the articulating surfaces, the least difference in the length or form of the bones of the two limbs, as well as in the contracting force of the muscles, necessarily causes sensible alterations in the progression, and renders it more or less difficult.

Of Leaping.

Of Leaping.

If we examine with attention this sort of motion, we will find that the body of man becomes a projectile, and that it follows all the laws of projectiles.

Leaping may take place directly upward, forward, backward, or laterally, &c.; but in all these cases we must consider the phenomena which precede and those that accompany it. Every species of leaping necessarily requires a previous flexion of one or many articulations of the trunk and inferior extremities; the sudden extension of the bent articulations is the particular cause of leaping.

Vertical leaping.

Let us suppose vertical leaping performed in the ordinary manner: the head is a little bent upon the neck; the vertebral column is bent forward; the pelvis is bent upon the thigh, the thigh upon the leg, and the leg upon the foot; in general the heel presses very lightly on the ground, or quits it entirely.

To this general state of flexion succeeds a rapid extension of all the articulations formerly bent; the different parts of the body are rapidly raised with a force which surpasses their weight by a quantity which is variable: thus the head and the thorax are directed upward by the extension and stretching of the vertebral column; the whole of the trunk is directed in the same manner by the extension of the pelvis upon the thighs; the thighs by rising rapidly act in the same manner upon the pelvis; the legs push the thighs in their turn. From all those united powers there results such a force of projection that the whole body is thrown upwards, and rises in proportion as the power is greater than the weight; it then falls upon the ground, presenting the same phenomena as any other body which falls by its weight.

In the general spring which produces leaping, the muscular action has not every where the same intensity: it ought evidently to be greater in that part where the weight is most considerable: on this account the muscles that determine the motion of extension of the leg upon the foot are those that have the greatest energy, since they must raise the whole weight of the body, and give it an impulse greater than its weight.

These muscles present also the most favourable disposition; they are very strong, and they are inserted in a direction perpendicular to the lever which they move (the heel-bone), and they act by an arm of the lever of considerable length.

We must remark, that the vertical leap does not result from any direct impulse, but from one which is made up of the opposite impulses of the body, and the inferior extremities, at the moment of leaping. In fact, the recovering of the head, of the vertebral column, and the pelvis, carries the trunk as much backward as upward; on the contrary, the motion of rotation of the thighs upon the tibia, brings the trunk as much forward as upward. The contrary takes place in the motion of the leg, which tends to direct the trunk upward and backward: when the leap is vertical, the efforts which throw the body forward or backward neutralize each other; the effort upwards is the only one which takes effect.

Leap backward and forward.

If the leap is forward, the rotatory motion of the thigh predominates over the impulsions behind, and the body is transported in that direction; if the leap is backward, the motion of extension of the vertebral column, and of the tibia upon the foot is the greatest.

The length of the bones of the inferior extremities is very favourable to the extent of leaping. The leap forward, by which we pass a greater space than in any other mode of leaping, is indebted for this advantage to the length of the thigh.

Of the spring.

Sometimes we run a greater or less distance before leaping; we then take the spring, as it is called; the impulsion which the body acquires by this preliminary force, added to the force of the leap, gives it a greater extent.

Use of the upper extremities in leaping.

The arms are not passive in the production of the leap; they approach the body in the instant in which the articulations are bent; they separate from it, on the contrary, the instant the body quits the ground. The resistance which they present to the muscles that raise them, enables these muscles to exert a power upon the trunk in drawing it upward which contributes to the production of the leap. The arms will be useful in this respect in proportion as they present a certain resistance to the muscles by which they are raised. The ancients had made this remark: they carried in their hands certain weights which they called *halteres*, when they wished to exercise themselves in leaping. By previously balancing the arms we may also favour the production of the horizontal leap, in giving an impulsion forward or backward to the upper part of the trunk. (63)

Leaping on one foot.

One of the lower limbs is sufficient to produce the leap, as when we hop; but it is easily understood that the leap is necessarily of less extent than when both feet are employed. Sometimes we leap with the two feet joined, and parallel to each other; sometimes one of the feet is carried forward during the projection of the body: this foot then receives the weight of the body the instant it touches the ground.

No species of impulsion can be given to the body at the instant of its rising by the plane upon which it rests, unless this plane is very elastic, and joins its re-action to the effort of the muscles which determine the projectile motion of the body.

In general the ground gives no assistance to the leap except by resisting the pressure of the foot. Every one knows that it is impossible to leap when the ground is soft, and gives way under the feet.

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(63) The account of the action of the muscles, of the motions and attitude of the human body here given, is, generally speaking, exact. Many further details may be obtained from Dr. Barclay's well-known work on muscular motion—and the curious will find much interesting disquisition on the subject in some of the latest numbers of our author's Physiological Journal. Though the subject is not exactly a wasting of time, yet all authors who take it up will do well to be brief. The flexions and extensions of a pasteboard dancing-master, the hauling and rehauling of the ropes of a ship, and the contraction and relaxation of animal muscles, are all, from the extreme similarity of their individual processes, utterly incapable of maintaining an interest in ordinary minds. As one packthread, rope, or muscle acts, so do all act, and the solitary variety afforded by the different hard or barbarous names of objects which are all so like each other, affords but a moment's refreshment to the spirit, wearied and disgusted as it is with the eternal sameness of expressions and ideas which it is compelled to repeat incessantly in this study.

The true theory of leaping is due to the celebrated Barthez of Montpellier; until his time the ideas respecting the explanation of this phenomenon were very imperfect. There is no analogy between the spring of an elastic curve and leaping.

Of Running.

Running results from the combination of the step and the leap, or rather it consists of a succession of leaps performed alternately by one limb, whilst the other is carried forward or backward, to be placed upon the ground, and produce the leap, as soon as the first has had time to be carried forward, or backward, according as the running may take place in the one or the other direction. We can run with more or less rapidity; but in running there is always an instant in which the body is suspended in the air, by the impulse which is given to it by the limb which remains behind, if we run forward. Of running

Running is distinguished by this character from rapid walking, in which the foot carried forward always touches the ground before that which is behind leaves it. For the same reasons that we mentioned in the article *Walking*, the least fatiguing sort of running is that which takes place upon a horizontal plane; that which takes place on an inclined plane, either ascending or descending, is always more or less fatiguing, and cannot be long continued.

We will not describe, even shortly, the different modifications of man's progressive motions, such as climbing, walking on crutches, on stilts, or artificial limbs. Neither shall we describe the different motions of dancing, in the common manner, or on the tight or slack rope; nor the motions of tumblers, of fencing, of riding, or of different professions, or trades: considerations of this kind would be very important; but they ought to form a complete treatise of animal mechanism, a work which is still wanting, notwithstanding those of Borelli and Barthez. We will say only a few words on Swimming.

Of Swimming.

The body of man is of a greater specific weight than water, consequently being placed in the midst of a mass of that liquid, it will tend towards the lower part of it: Of Swimming.

this motion will be so much more easy as the surface it presents to the water is less. If, for example, the body is placed vertically, the feet below and the head above, it will go much quicker to the bottom, than if it were placed horizontally, on the surface of the liquid. Some individuals, however, have the faculty of rendering themselves specifically lighter than the water, and therefore they remain on the surface without any effort. Their art consists in drawing a great quantity of air into the chest, the lightness of which counterbalances the tendency which the body has to sink in the water.

Swimmers do not follow this method to support themselves upon the surface of the water; they are supported by the motions which their limbs perform. The motions of the swimmer are intended to support his body on the water, or to determine its progression.

Whatever is his intention, the swimmer must so act upon the water that it may present a resistance sufficient to support his body, or to permit its displacement: with this intention, it is necessary only to strike it quicker than it can escape, and to carry the action of the hands or the feet rapidly over a great many different points, because the resistance is great in proportion to the mass of water that is displaced. The motions of the inferior extremities in swimming in the ordinary way, *la brassée*, have analogy with those which they perform in leaping.

There are an immense variety of ways of swimming; but on the whole it is necessary to strike the water quicker than it can be displaced.

Man cannot fly; his weight, compared to that of the air, is too great, and the force of the contraction of his muscles is too weak. Every attempt made by man to sustain himself in the air, by the assistance of machines like the wings of birds, has uniformly failed.

Of the Attitudes and Motions at different ages.

Attitudes and motions in different ages.

From the embryo state to the age of eighteen or twenty years, the bones constantly change their form, and size; during the time, therefore, that ossification continues, the attitudes and motions must present changes analogous to those that the skeleton undergoes. We have already seen that the muscles and muscular contraction are also modified by the state of the fœtus, by infancy, youth, &c.; the same circumstances have much influence upon the motions. Generally at twenty, or twenty-two years, the growth of the bones is finished; but they continue to grow in thickness beyond adult age: then every sort of increase ceases, and the changes that the bones suffer up to decrepit old age relate only to the nutrition of these organs, and their chemical composition.

Attitudes of the fœtus.

The position of the fœtus in the uterus depends on circumstances still very little known; its head is generally turned downward, which probably depends upon its weight being more considerable; but why does the occiput correspond almost always to the part of the pelvis above the left *acetabulum?*

Why does it sometimes happen that the fœtus is placed in a quite different manner, for example, with the thighs below, sometimes directed to the right, sometimes to the left side? This is not known.

The thighs of the fœtus are bent upon the abdomen, the legs are applied to the thighs, the arms are crossed upon the anterior part of the trunk, and the head is generally bent upon the chest; so that the fœtus fills the least space possible. This position does not depend on a continued muscular contraction, it is the effect that the muscles have to shorten themselves: in a more advanced age, we often assume this position when we wish to slacken all the muscles.

Motions of the fœtus.

Four months after conception the fœtus begins to make partial motions, and perhaps some slight motions that remove the whole body. These motions are irregular, they take place at variable periods, they continue until the end of pregnancy, and, to judge by the places where they are felt, they are frequently exerted by the inferior extremities. We cannot believe that they depend on the will, for the intellect does not then exist, and the acephalous fœtuses, that is, those without brain, present them as well as the others.

Attitudes of the child.

A new-born child can take no position of itself, it keeps that which is given it; it is, however, perceived that lying on the back pleases it best, and which in fact is in correspondence with the weakness of its muscular system. Its superior and inferior extremities offer pretty strong motions; its physiognomy is without expression.

Motions of the child.

At the end of two or three months the child changes its attitude of itself when it is left at liberty, it lies on its side, on its belly, turns its head; the motions of its limbs are more numerous, and more energetic; it seizes more forcibly the bodies which are presented to it, and carries them to its mouth; when sucking it compresses more forcibly the breast of its mother, &c.: but it is not able to stand, nor even to sit. The principal reasons of it are: the head is proportionally too voluminous, and too heavy; it falls forward, not being suitably sustained by muscular power; the weight of the pectoral, and particularly of the abdominal viscera, is very great; the vertebral column presents only one curve, the convexity of which is behind. The posterior muscles of the trunk are much too weak to resist the inclination of the vertebral column to fall forward; but besides, the spinous processes do not exist, so that the arm of the lever by which they act is very short, a circumstance unfavourable to their action; the pelvis, very small, and very much inclined forward, scarcely supports the weight of the abdominal viscera. The inferior extremities are very little developed, and their muscles are too weak to balance for an instant the inclination of the body forward. Any sort of standing is then impossible. However, it frequently happens that the child, by using its superior and inferior limbs, can move itself small distances; and because this sort of motion has an analogy with that of certain animals, some sophists have pretended that man was naturally a quadruped, and that standing on two feet was an acquirement dependent on social life. In order that this idea should have some foundation, the organs of motion in the adult ought to be disposed like those of the child: but we have seen that they are quite different.

Reasons why the child cannot stand.

Towards the end of the first year, sometimes at the beginning of the second, sooner or later, by the effect of development of the bones, of the muscles, &c., by the diminution of the volume, and of the proportional weight of the head, of the abdominal viscera, &c., the child succeeds in standing, but it cannot yet walk; it soon accomplishes this by taking hold of bodies that are near it; at last, it walks alone, but tottering, and the least obstacle makes it fall.—The step is the only sort of locomotion it can exert at first; in general, it is a considerable time before the child is able to run, and still longer before it can leap; but after it is once confirmed in the different progressive motions, it is in continual agitation; it acquires agility and address: it then contracts a taste for different kinds of sports, which almost all, particularly with boys, serve to exercise the organs of locomotion and understanding.

Sports of children.

In respect to physiology, the sports of children are worthy of remark. Let them be studied with attention, and we will see that they are the models of the actions of the adult; the same resemblance may be established in young animals, which are also the same, in a certain degree, as those they perform afterwards.

In the sports of children, we must not confound those that are purely instinctive with those that depend upon imitation.

Attitudes and motions from youth to adult age.

From youth to adult age, and even beyond it, all the phenomena that relate to the attitudes and motions are in their greatest perfection; with age they become more energetic only, but in old age they suffer a notable alteration, which depends on the weakened state of muscular contraction: As this contraction does not then take place without pain, and unsteadiness, the attitudes and motions are in consequence affected. The old man, whether walking or standing, is generally bent forward; the pelvis bent upon the thighs, these upon the legs; and lastly, the legs are inclined forward upon the feet. This state of general semiflexion depends on the weakness of the muscular force, which has no longer sufficient energy to keep the body straight.

Attitudes and motions of the old.

The old man has also a great advantage in using a stick, by which means he enlarges the base of support, and transmits the weight of the upper parts of the body directly to the ground.

The motions are of an extreme difficulty in decrepitude, sometimes entirely impossible.

Relations of the Sensations with the Attitudes and Motions.

Relations of sensations with attitudes and motions.

The sensations affect the attitudes and motions; these, in their turn, have an influence upon the sensations.

Relations of sight with attitudes and motions.

Sight contributes much to the firmness of most of our attitudes; we judge by it of the position of our body in respect of those bodies that surround us. Thus, when we are deprived of this means of judging of our equilibrium, as when we are on the top of a house, or on any elevated place, where we are only surrounded by the air, our standing on two feet becomes uncertain, and it sometimes happens that we cannot stand at all.

The utility of sight is still greater if the base of support is very narrow. A rope-dancer could not stand erect, if he were not continually directed by the eye, as to the position necessary to be preserved, in order that the perpendicular drawn from his centre of gravity may fall upon the base of support. Generally, whatever is our attitude, it is very unstable, if we cannot use the sight. We may ascertain this fact in examining the standing posture and attitudes of a blind person.

If sight is of so great assistance to the attitudes, it ought to be much more so in the different sorts of partial and locomotive motions. In fact, sight enlightens and favours our motions; it gives them precision and the necessary rapidity; it directs them in almost all cases. If the eyes of an active man are bound he loses nearly all his advantages; he walks timidly, particularly if he does not know perfectly the place in which he is; all his motions have the same character: the same phenomena exist in blind people, who may be easily known by their slightest motions, at least if they are not motions which are very familiar to them. The absence of sight disposes to immobility; the use of this sense, on the contrary, excites to motion: every one knows that we are strongly tempted to seize and touch the objects that we see for the first time.

Important distinction relative to the gestures.

The consideration of the relations of sight and motion cause us to remark that those which are intended to express our intellectual operations are instinctive, and that they may be comprehended under the general name of *gestures*, may be divided into those that are intimately connected with organization, and consequently exist always in man, in whatever state he is; and into those that arise in the social state, and become perfect along with it.

Gestures natural or instinctive.

The first are intended to express the most simple wants, vivid internal sensations, as joy, sorrow, fright, &c.; as the animal passions, they are to the motions what the cry is to the voice. They are observed in the idiot, the savage, the person born blind, as well as in civilized man who enjoys all the physical and moral advantages.

Acquired, or social gestures.

The gestures of the second sort can exist only in society, they suppose sight and intellect; they are not then seen in the person blind from birth, in the idiot, nor in an individual who has always lived alone. They may be called *acquired or social gestures*, by analogy with acquired voice. Probably in procuring sight to a person blind from birth, we might at the same time give him the acquisition of these particular gestures of which we speak. The gestures of a person born blind may be supposed exactly in the same case as the voice of a person deaf from birth. These two phenomena mutually supply each other.

The deaf and dumb person makes a continual use of gestures, and carries them to a high degree of perfection; on the contrary, the voice alone is used as a means of expression by the blind person: thence his taste for singing and speech, and the accent he gives to his voice.

Relations of hearing with the motions.

The hearing is not without influence upon the motions; this sense sometimes contributes with the sight to direct, and particularly to measure them, to make them return at equal intervals, and to produce a certain number of them in a given time, as in dancing or military marches. It has been long remarked that measured movements executed to the sound of music or the noise of a drum, are less fatiguing than others: this is because they are regular, that every muscle contracts and relaxes alternately, and the time of repose is equal to that of action. It ought to be added that music and even noise excites to motion.

Relations of the smell and taste to the attitudes and motions.

The relations of smell and taste with the attitudes and motions are too unimportant to be noticed. With regard to touch, as muscular contraction is inseparable from it, (for without it sensation cannot take place,) we may easily see that it is intimately connected with all the phenomena that depend on muscular contraction.

Relation of the internal sensations to the attitudes and motions.

The internal sensations have not less influence upon the different attitudes and motions of the body than the external ones. Who could not recognise by his position a man who might have a severe pain, or a sensation of another kind? We may even, in a certain degree, determine the seat of a painful affection, by the particular position or motion of the sick person. It is well known that a violent colic causes the person affected to bend the chest upon the pelvis, and to place the hands upon the abdomen; that a violent stitch in the side causes him to lie upon the side affected; that the presence of a stone in the bladder causes the patient to assume particular attitudes.

We have seen the influence of sensations upon the attitudes and motions; these re-act in the same way upon the action of the senses; the different attitudes are favourable or unfavourable to the development of the external sensations; the motions have not a less share in it. There are partial motions, proper to every sense, and which favour its action; besides, almost all of the senses have particular muscles, that make an essential part of the sensitive apparatus, as is seen in the ear, the eye, the hand, &c.

Relations of the Attitudes and Motions to the Will.

Relations of the will to the attitudes and motions.

The attitudes and motions that we have described, are generally called *voluntary*, because they are said to be under the immediate influence of the will. This operation is true in a certain respect, but it is not so in others; we must therefore explain this point.

The will is the occasion of the motions, but does not directly produce them.

After a determination of the will, a motion is produced; no doubt the will has been the occasion of its development: but all the phenomena which take place, even for the production of motion, are not any longer under the power of the will. I can move my hand or my arm, but I cannot contract either singly or wholly the muscles of these parts, if I have no idea of a motion to be produced. It is the same with the contraction of all the muscles, which are considered as entirely subject to the will. How would we separately contract the external obturator, or any other muscle which does not produce a determined motion peculiar to itself? It would be impossible.

We may then affirm that the will is the determining cause of motion; but even the production of the muscular contraction, which is necessary to its taking place, does not depend on this cerebral action; it is purely instinctive.

Influence of the brain and of the spinal marrow on the production of motion.

After these considerations, we ought to conclude that the will, and the action of the brain which produces directly muscular contraction, are two distinct phenomena; but the direct experiments of modern physiologists, and particularly of *Legallois*, have put this truth in the strongest light. These experiments have demonstrated that the will has more particularly its seat in the cerebrum and cerebellum. On the contrary, the direct cause of motion seems to have its seat in the spinal marrow. If we separate the spinal marrow from the rest of the brain by a section made behind the occipital bone, we prevent the will from determining and directing the motions; but they are nevertheless produced: in reality, 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 the will, we can easily conceive why, in certain cases, the motions are not produced, though commanded by the will; and why in certain circumstances of a contrary nature very extensive and energetic motions are developed without any participation of the will, as is seen frequently in many diseases.

For the same reason we conceive why it is very difficult, sometimes impossible, to take an attitude which is new to us, or to perform a movement for the first time; why are all the arts, such as dancing, fencing, &c. which are founded upon the rapidity and precision of our motions, acquired only by long exercise? why, in a word, does it happen that we often execute motions more perfectly in turning our attention from them, than in paying the greatest attention possible?

Relations of Attitudes and Motions with Instinct and the Passions.

We have seen that a great part of what are called *voluntary motions* and *attitudes*, are under the dominion of instinct; a great number of attitudes and motions, both partial and general, essentially depend upon it.

All the instinctive feelings essentially attached to organization, such as sorrow, fear, joy, hunger, thirst, carried to a certain degree, have attitudes and modes of motion which are proper to them, and by which their existence is known: it is the same with the natural passions, and all the instinctive phenomena developed in the social state.

Influence of instinct and the passions upon the attitudes and motions.

Many passions excite to motion, augment much the intensity of muscular force, as we have examples in excessive joy, anger, in certain cases of fear, &c. Other passions stupify, and render every sort of motion impossible, such as violent grief, a certain sort of terror; extreme joy often produces the same effect: on this account, the art of pantomime is exerted with success in painting the violent passions.

Relations of the Motions to Voice.

Relations of the motions to voice.

The relations of motions to the voice are intimate, as they ought, since these two sorts of phenomena are the immediate effect of muscular contraction, with this difference, that, in the voice, the effect is heard, whereas it is seen in the motions.

There are motions essentially attached to organization; crying is in that predicament. There is a voice which is acquired by social life; a great many motions are acquired in the same manner. Voice and motion are united for the production of speech. These two phenomena are our principal and almost only means of expression; they assist, and sometimes supply each other mutually. A man who expresses himself badly, gesticulates a great deal; it is the contrary with a person who has an easy elocution. In the great passions, the two means of expression are united: we rarely express a lively sentiment without joining gesture to speech.

It ought to have been remarked, that the modifications which the voice and the motions undergo by age, are very analogous; we would have a similar result were we to study the changes they suffer by sex, temperament, habit, &c.

We shall terminate, by these considerations, the description of the relative functions. The common character of these functions is that of being periodically suspended, or, in other terms, of being plunged at intervals in sleep. It might then appear suitable that the history of sleep should follow immediately that of the relative functions; but as the nutritive and generative functions are also much influenced by sleep, we prefer postponing the study of the former until we have finished the description of these functions.

OF THE NUTRITIVE FUNCTIONS.

The common design of the nutritive functions is nutrition; namely, that intestine motion, by which all the parts of the body are decomposed and recomposed simultaneously.

These functions are six in number, viz.

Nutritive Functions.

1st, Digestion;
2d, Absorption, and the course of the chyle;
3d, The course of the lymph;
4th, The course of the veinous blood;
5th, Respiration;
6th, The course of the arterial blood.

After the description of these functions, and of the relations which they have with each other, as well as with the *functions of relation*, we will study, not as functions, but as independent organic actions, the different secretions, and will finish with the history of the nutritive motion itself. Secretions and nutrition.

Of Digestion.

The immediate object of digestion is the formation of chyle, a matter destined for the reparation of the continual waste of the animal economy. The digestive organs contribute also in many other ways to nutrition.

Of the Aliments, and of Drinks.

The name of aliment is given generally to every substance which, being subjected to the action of the organs of digestion, is capable by itself of affording nourishment. In this sense an aliment is extracted necessarily from vegetables or animals; for only those bodies that have possessed life are capable of serving usefully in the nutrition of animals during a certain time. This manner of regarding aliments appears rather too confined. Why refuse the name of aliments to substances which, in reality, cannot of themselves afford nourishment, but which contribute efficaciously to nutrition, since they enter into the composition of the organs, and of the animal fluids? Such are the muriate of soda, the oxide of iron, silica, and particularly water, which is found in such abundance in the bodies of animals, and is so necessary to them. It appears preferable to me, to consider as an aliment every substance which can serve in nutrition; establishing, however, the important distinction between substances which can nourish of themselves, and those which are useful to nutrition only in concert with the former.* Of aliments and drinks.

* It has been said, after Hippocrates, "that there are many species, but yet only one *aliment*. This proposition has never appeared to me to be very clear; if they mean that in one substance there is only one nutritive part, still that part will vary with each individual aliment. Is it that all aliments, by ultimate decomposition, contribute to form *one* substance,—the chyle? Even this is not exactly true, since chyle varies in its qualities according to the food from which it has been produced. Do authors believe that all aliments renew in the blood a particular substance, alone capable of nutrition? the *quod nutrit* of the ancients? But does such a substance exist? Or, in fine, do they imagine that in the boundless variety of aliments there constantly exists a particular, identical, essentially nutritive principle? There is nothing less proved.

Of Aliments.

Of the aliments. In respect to their nature, aliments are different from each other, by the proximate principles which predominate in their composition. They may be distinguished into nine classes:

1st, *Farinaceous aliments:* wheat, barley, oats, rice, rye, maize, potatoe, sago, salep, peas, haricots, lentils, &c.

2d, *Mucilaginous aliments:* carrots, salsafy (goats-beard), beet-root, turnip, asparagus, cabbage, lettuce, artichoke, cardoons, pumpions, melons, &c.

3d, *Sweet aliments:* the different sorts of sugar, figs, dates, dried grapes, apricots, &c.

4th, *Acidulous aliments:* oranges, gooseberries, cherries, peaches, strawberries, raspberries, mulberries, grapes, prunes, pears, apples, sorrel, &c.

5th, *Fatty and oily aliments:* cocoa, olives, sweet almonds, nuts, walnuts, the animal fats, the oils, butter, &c.

6th, *Caseous aliments:* the different sorts of milk, cheese, &c.

7th, *Gelatinous aliments:* the tendons, the aponeurosis, the chorion, the cellular membrane, young animals, &c.

8th, *Albuminous aliments:* the brain, the nerves, eggs, &c.

9th, *Fibrinous aliments:* the flesh and the blood of different animals.

We might add to this list a great number of substances that are employed as medicines, but which doubtless are nutritive, at least in some of their immediate principles: such are manna, tamarinds, the *pulp of cassia*, the extracts and saps of vegetables, the animal or vegetable decoctions, commonly called *ptisanes*, &c.

Preparation of aliments. Amongst aliments there are few employed such as nature presents them; they are generally prepared, and disposed in such a manner as to be suitable for the action of the digestive organs. The preparations which they undergo are infinitely various, according to the sort of aliment, the people, the climates, customs, the degree of civilization: even fashion is not without its influence on the art of preparing aliments.

In the hand of the skilful cook, alimentary substances almost entirely change their nature:—form, consistence, odour, taste, colour, composition, &c., every thing is so modified that it is impossible for the most delicate tastes to recognise the original substance of certain dishes.

The useful object of cookery is to render aliments agreeable to the senses, and of easy digestion; but it rarely stops here: frequently with people advanced in civilization its object is to excite delicate palates, or difficult tastes, or to please vanity. Then, far from being a useful art, it becomes a real scourge, which occasions a great number of diseases, and has frequently brought on premature death. Object of cookery.

Of Drinks.

We understand, by *drink*, a liquid which, being introduced into the digestive organs, quenches thirst, and so by this repairs the habitual losses of our fluid humours; the drinks ought to be considered as real aliments. Of drinks.

The drinks are distinguished by their chemical composition:

1st, Water of different sorts, spring water, river water, water of wells, &c.

2d, The juices and infusions of vegetables and animals: juices of lemon, of gooseberries, whey, tea, coffee, &c.

3d, Fermented liquors: the different sorts of wine, beer, cyder, perry, &c.

4th, The alcoholic liquors: brandy, alcohol, ether, kirchenwasser, rum, rack, ratafia.

Apparatus of Digestion.

If we judge of the importance of a function by the number and variety of its organs, digestion ought to be placed in the first rank; no other function of the economy presents such a complicated apparatus. Digestive organs.

There always exists an evident relation between the sort of aliment proper for an animal and the disposition of its digestive organs. If, by their nature, the aliments are very different from the elements which compose the animal: if, for example, it is graminivorous, the dimensions of the apparatus will be more complicated, and more considerable; if, on the contrary, the animal feeds on flesh, the digestive organs will be fewer and more simple, as is seen in the carnivorous animals. Man, called to use equally animal and vegetable aliments, keeps a mean between the graminivorous and carnivorous animals, as to Relations of the digestive organs with the aliments.

the disposition and complication of his digestive apparatus, without deserving, on that account, to be called omnivorous. Is it not known that a great number of the substances upon which animals feed can be of no use for the support of man?

Digestive canal.

We may represent the digestive apparatus as a long canal differently twisted upon itself, wide in certain points, narrow in others, susceptible of contracting or enlarging its dimensions, and into which a great quantity of fluids is poured by means of different ducts. The canal is divided into many parts by anatomists: 1st, the mouth; 2d, the pharynx; 3d, the *œsophagus;* 4th, the stomach; 5th, the small intestines; 6th, the great intestines; 7th, the anus.

Structure of the digestive canal.

Two membranous layers form the sides of the digestive canal in its whole length. The inner layer, which is intended to be in contact with the aliments, consists of a mucous membrane, the appearance and structure of which vary in every one of the portions of the canal, so that it is not the same in the pharynx as in the mouth, nor is it in the stomach like what it is in the œsophagus, &c. In the lips and the anus this membrane becomes confounded with the skin. The second layer of the sides of the digestive canal is muscular; it is composed of two layers of fibres, one longitudinal, the other circular. The arrangement, the thickness, the nature of the fibres which enter into the composition of these strata are different, according as they are observed in the mouth, in the œsophagus, or in the large intestine, &c.

Vessels of the digestive canal.

A great number of blood vessels go to, or come from the digestive canal; but the abdominal portion of this canal receives a quantity incomparably greater than the superior parts. This presents only what are necessary for its nutrition, and the inconsiderable secretion, of which it is the seat; whilst the number and the volume of the vessels that belong to the abdominal portion show that it must be the agent of a considerable secretion. The chyliferous vessels arise exclusively from the small intestine.

As to the nerves, they are distributed to the digestive canal in an order inverse to that of the vessels; that is, the cephalic parts, *cervical* and *pectoral*, receive a great deal more than the abdominal portion, the stomach excepted, where the two nerves of the eighth pair terminate. The other parts of the canal scarcely receive any branch of the cerebral nerves. The only nerves that are observed, proceed from the *subdiaphragmatic* ganglions of the great sympathetic. We will see, farther on, the relation that exists between the mode of distribution of the nerves, and the functions of the superior and inferior portions of the digestive canal.

Organs which pour fluids into the intestinal canal.

The bodies that pour fluids into the digestive canal, are, 1st, the *digestive mucous membrane* itself; 2d, isolated follicles that are spread in great number in the whole length of this membrane; 3d, the *agglomerated follicles* which are found at the isthmus of the throat, between the *pillars* of the *velum* of the palate, and sometimes at the junction of the *œsophagus* and the stomach; 4th, the *mucous glands* which exist in a greater or less number in the sides of the cheeks, in the roof of the palate, around the œsophagus; 5th, the *parotid*, the *submaxillary*, and *sublingual glands*, which secrete the saliva of the mouth; the *liver* and the *pancreas;* the first of which pours the bile, the second the pancreatic juice, by distinct canals, into the superior part of the small intestine, called *duodenum*.

All the digestive organs contained in the abdominal cavity are immediately covered, more or less completely, by the serous membrane called the *peritoneum*. This membrane, by the manner in which it is disposed, and by its physical and vital properties, is very useful in the act of digestion, by preserving to the organs their respective relations, by favouring their changes of volume, by rendering easy the sliding motions which they perform upon each other, and upon the adjoining parts. We will give the necessary details of the digestive apparatus, according as we explain its functions; we will here make only some remarks upon the digestive organs, considered in the state of life, but whilst they do not serve in the digestion of the aliments.

Remarks upon the digestive Organs of Man, and living Animals.

The surface of the mucous digestive membrane is always lubrified by a glutinous adhesive matter, more or less abundant, that is seen in greatest quantity where there exist no follicles,—a circumstance which seems to indicate that these are not the only secreting organs. A part of this matter, to which is given generally the name of *mucous*, continually evaporates, so that there exists habitually a certain quantity of vapours in all the points of the digestive canal. The chemical nature of this substance, as taken at the intestinal surface, is still very little known. It is transparent, with a light grey tint; it adheres to the membrane which forms it; its taste is salt, and its acidity is shown by the re-agents: its formation still continues some time after death. That which is formed in the mouth, in the pharynx, and in the *œsophagus*, goes into the stomach mixed with the saliva, and the fluid of the mucous glands, by movements of deglutition, which succeed each other at near intervals. According to this detail, it would appear that the stomach ought to contain, after it has been some time empty of aliments, a considerable quantity of a mixture of mucous, of saliva, and follicular fluid. This observation is not proved, at least in the greatest number of individuals. However, in a number of persons, who are evidently in a particular state, there exist, in the morning, in the stomach, many ounces of this mixture. In certain cases it is foamy, slightly troubled, very little viscous, holding suspended some flakes of mucus; its taste is quite acid, not disagreeable, very sensible in the throat, acting upon the teeth, so as to diminish the polish of their surface, and rendering their motion upon each other more difficult.—This liquid reddens paper stained with turnsol.

Acid liquid of the stomach.

Liquid of the stomach not acid.

In the same individual, in other circumstances, and with the same appearances as to colour, transparency, and consistency, the liquid of the stomach had no savour, nor any acid property; it is a little salt: the solution of potass, as well as the nitric and sulphuric acids, produced in it no apparent change. Doctor Pinel, formerly one of my pupils, who possesses the faculty of vomiting when he pleases, sent me, some time since, about three ounces of a liquid that he had extracted from his stomach the same morning. This liquid, which presented the same physical properties as the preceding, was examined by M. Thenard; he found it composed of a great quantity of water, a little mucus, and some salts, with a base of soda and lime; it presented no acidity, neither to the tongue, nor the chemical tests.

Composition of the liquid acid of the stomach.

The same physician sent me, very lately, about two ounces of a liquid obtained in the same manner. M. Chevreul analysed it, and found:—A great deal of water, a considerable quantity of mucus, some lactic acid of

Berzelius, combined with an animal matter, soluble in water, and insoluble in alcohol, a little hydro-chlorate of ammonia, and hydro-chlorate of potass, and a certain quantity of hydro-chloràte of soda.

With regard to the quantity of this liquid, M. Pinel observed, that if, before vomiting it up, he should swallow a mouthful of water, or of any sort of aliment, he could obtain, in very little time, a half pound of it. M. Pinel thinks he has observed that the savour of this same liquid varies according to the sort of aliment he has taken the night before.

When we examine the dead bodies of persons killed by accident, the stomach not having received any aliments nor drink for some time, this organ contains only a very few acid mucosities adhering to the coats of the stomach, part of which, in the *pyloric* portion of that viscus, appears reduced to chyme. It is, then, very probable, that the liquid which ought to be in the stomach is digested by this viscus as an alimentary substance, and that this is the reason why it does not accumulate there.

In animals whose organization approaches to that of man, such as dogs and cats, there is no liquid found in the stomach after one, or many days of complete abstinence; there is seen only a small quantity of viscous mucosity adhering to the sides of the organ, towards its *splenic* extremity. This matter has the greatest analogy, both chemical and physical, with that which is found in the stomach of man. But, if we màke these animals swallow a body which is not susceptible of being digested, as a pebble for example, there forms, after some time, in the cavity of the stomach, a certain quantity of an acid liquid, mucous, of a greyish colour, sensibly salt, which, in its composition, is nearly the same as that found sometimes in man, the approximative analysis of which we have just given according to M. Chevreul.

Gastric juice.

This liquid, resulting from the mixture of the mucosities of the mouth, of the pharynx, of the œsophagus and the stomach, with the liquid secreted by the follicles of the same parts and with the saliva, has been called by physiologists the *gastric juice*, and to which they have attributed particular properties.

Mucus of the small intestine.

In the small intestine there is also formed a great quantity of mucous matter, which rests habitually attached to the sides of the intestine; it differs little from that of which we have spoken above; it is viscid, tough, and has a salt and acid savour; it is renewed with great rapidity. If the mucous membrane of this intestine is laid bare, in a dog, and the layer of mucus absorbed by a spunge, it will appear again in a minute. This observation may be repeated as often as we please, until the intestine becomes inflamed by the contact of the air, and foreign bodies.

The mucus of the stomach penetrates into the cavity of the small intestine only under the form of a pulpous matter, greyish and opaque, which has all the appearance of a particular chyme.

Manner in which the bile flows in the small intestine.

It is at the surface of this same portion of the digestive canal that the bile is delivered, as well as the liquid secreted by the pancreas. I do not believe that there has ever been any observation made of the manner in which the bile and the pancreatic liquid flow in a living man. In animals, such as dogs, the flowing of these liquids takes place at intervals; that is, about twice in a minute, there is seen to spring from the orifice of the *Ductus choledochus*, or biliary canal, a drop of bile, which immediately spreads itself uniformly in a sheet upon the surrounding parts, which are already impregnated with it; there is, also, constantly found a certain quantity of bile in the small intestine.

Manner in which the pancreatic fluid flows into the small intestine.

The flowing of the liquid formed by the pancreas takes place much in the same manner, but it is much slower: sometimes a quarter of an hour passes before a drop of this fluid springs from the orifice of the canal which pours it into the intestine.

I have seen, however, the flowing of the pancreatic fluid take place, in certain cases, with considerable rapidity.

The different fluids deposited in the small intestine, which are, the chymous matter that comes from the stomach, the mucus, the follicular fluid, the bile, and the pancreatic liquid, all mix together; but, on account of its properties, and perhaps of its proportions, the bile predominates, and gives to the mixture its proper taste and colour. A great part of this mixture descends towards the large intestine, and passes into it; in this passage, it becomes more consistent, and the clear yellow colour which it had before becomes dark, and afterwards greenish. There are, however, in this respect, strong individual differences.

Mucus of the large intestine.

In the large intestine, the mucous and follicular secretion appear less active than in the small intestine; the mixture of fluids which comes from the small intestine acquires in it more consistence; it contracts a fetid odour, analogous to that of ordinary excrements: it has, besides, the appearance of it, by its colour, odour, &c.

The knowledge of these facts enables us to understand how a person who uses no aliments, can continue to produce excrements, and how, in certain diseases, their quantity is very considerable, though the sick person has been long deprived of every alimentary substance, even of a liquid kind. Round the anus exist follicles, which secrete a fatty matter of a singularly powerful odour.

Of the gases contained in the intestinal canal.

We find gas almost always in the intestinal canal; the stomach contains only very little. The chemical nature of these gases has not yet been examined with care; but as the saliva that we swallow is always more or less impregnated with atmospheric air, it is probably the atmospheric air, more or less changed, which is found in the stomach. At least, I have ascertained, by experience, that it contains carbonic acid. The small intestine contains only a small quantity of gas; it is a mixture of carbonic acid, of azote, and hydrogen. The large intestine contains carbonic acid, azote, and hydrogen, sometimes carbureted, sometimes sulphurated. I have seen twenty-three per cent. of this gas in the rectum of an individual lately executed, whose large intestine contained no excrement.

What is the origin of these gases? Do they come from without? Are they secreted by the mucous digestive membrane, or do they rather result from the reaction of the elements which compose the matters contained in the intestinal canal? This question will be examined afterwards; we may remark, however, that there are circumstances in which we swallow a great deal of atmospheric air without knowing it.

Muscular layer of the digestive canal.

Different modes of contraction of the fibres of the digestive canal.

The muscular layer of the digestive canal deserves to be remarked, in respect to the different modes of contraction it presents. The lips, the jaws, in most cases the tongue, the cheeks, are moved by a contraction, entirely like that of the muscles of locomotion. The roof of the palate, the pharynx, the œsophagus, and the tongue in certain particular circumstances, offer many motions, which have a manifest analogy with muscular contraction, but which are very different from it, because they take place without the participation of the will. I have, however, had occasion to see persons who could move voluntarily the *velum* of the palate, and the superior part of the pharynx.

This does not imply that the motions of the parts I have just named are beyond the influence of the nerves; experience proves directly the contrary. If, for example, the nerves that come to the œsophagus are cut, this tube is deprived of its contractile faculty.

Motion of the œsophagus.

The muscles of the *velum* of the palate, those of the pharynx, the superior two-thirds of the œsophagus, scarcely contract like digestive organs, but when they act in permitting substances to pass from the mouth into the stomach. The inferior third of the œsophagus presents a phenomenon which is important to be known: this is an alternate motion of contraction and relaxation which exists in a constant manner. The contraction commences at the union of the *superior two-thirds* of the canal with the *inferior third*; it is continued, with a certain rapidity, to the insertion of the œsophagus into the stomach: when it is once produced it continues for a time, which is variable: its mean duration is, at least, thirty seconds. Being so contracted in its inferior third, the œsophagus is hard and elastic, like a cord strongly stretched. The relaxation which succeeds the contraction happens all at once, and simultaneously in all the contracted fibres; in certain cases, however, it seems to take place from the superior to the inferior fibres. In the state of relaxation, the œsophagus presents a remarkable flaccidity, which makes a singular contrast with its state of contraction.

Motion of the œsophagus.

This motion of the œsophagus depends on the nerves of the eighth pair. When these nerves of an animal are cut, the œsophagus no longer contracts, but neither is it in the relaxed state that we have described; its fibres being separated from nervous influence, shorten themselves with a certain force, and the canal is found in an intermediate state between contraction and relaxation. The vacuity or distension of the stomach, has an influence upon the duration and intensity of the contraction of the œsophagus.*

* These alternate movements of the œsophagus are not found in the horse; but the crura of his diaphragm have a peculiar action on the car-

From the inferior extremity of the stomach to the end of the intestine rectum, the intestinal canal presents a mode of contraction which differs, in almost every respect, from the contraction of the sub-diaphragmatic portion of the canal. This contraction always takes place slowly, and in an irregular manner; sometimes an hour passes before any trace of it can be perceived; at other times many intestinal portions contract at once. It appears to be very little influenced by the nervous system: for example, it continues in the stomach after the section of the nerves of the eighth pair; it becomes more active by the weakness of animals, and even by their death; in some, by this cause, it becomes considerably accelerated; it continues though the intestinal canal is entirely separated from the body. The pyloric portion of the stomach, the small intestine, are the points of the intestinal canal where it is presented oftenest, and most constantly. This motion, which arises from the successive or simultaneous contraction of the longitudinal or circular fibres of the intestinal canal, has been differently denominated by authors: some have named it *vermicular*, others *peristaltic*, others again, *sensible organic contractility*, *&c.* Whatever it is, the will appears to exert no sensible influence upon it. Peristaltic motion of stomach and intestines.

The muscles of the anus contract voluntarily.

The supra-diaphragmatic portion of the digestive canal is not susceptible of undergoing any considerable dilatation; we may easily see, by its structure, and the mode of contraction of its muscular coat, that it is not intended to allow the aliments to remain in its cavity, but that it is rather formed to carry these substances from the mouth into the stomach: this last organ, and the large intestine, are evidently prepared to undergo a very great distension; substances, also, which are introduced into the alimentary canal, accumulate, and remain for a time, more or less, in their interior.

The diaphragm, and the abdominal muscles, produce a sort of perpetual agitation of the digestive organs contained in the abdominal cavity; they exert, upon these organs, a continual pressure, which becomes sometimes very considerable. We will see, farther on, how these two causes,

diac extremity of that tube, which does not take place in animals that vomit easily. See my experiments, *Bulletin de la Société Philomatique, an.* 1815.

united or separated, contribute to the different acts of digestion.

Of Hunger and Thirst.

Hunger and thirst.

Digestion in man, and the animals, requires a certain number of actions to procure and seize upon the aliments, and finally to introduce them into the stomach: this introduction ought to cease when the stomach is full, or it ought to be done only in proportion to the wants of the economy; it is generally convenient that it should not take place until after the former digestion is terminated; there are, also, other circumstances in which it would be hurtful. It was then necessary that man, and the animals, should be informed of the proper time to put liquid, or solid aliments, into the stomach, and of the circumstances in which it would be improper to do so. Nature has provided for this important end by the development of many instinctive feelings, which indicate the wants of the economy, and the particular state of the digestive organs. These indicative feelings vary according to our individual wants; they may be divided into those which induce us to make use of any substance, and those that render it an object of aversion. The first relate to *hunger* and *thirst;* the second to *satiety* and *disgust.*

Of Hunger.

Of hunger.

The want of solid aliments is characterized by a peculiar sensation in the region of the stomach, and by a general feebleness, more or less marked. This feeling is generally renewed after the stomach has been for some time empty; it is variable in its intensity and its nature in different individuals, and even in the same individual. In some its violence is excessive, in others it is scarcely felt; some never feel it, and eat only because the hour of repast is come. Many persons perceive a drawing, a pressure more or less painful in the epigastric region, accompanied by yawnings, and a particular noise, produced by the gases contained in the stomach, which becomes contracted. When this want is not satisfied it increases, and may become a severe pain: the same takes place with the sensation of weakness and general fatigue, which is felt, and which may increase, so as to render the motions difficult, or even impossible.

Phenomena of hunger.

Authors distinguish in hunger, local phenomena, and general phenomena.

This distinction is good in itself, and may be useful for study; but have not mere gratuitous suppositions been described as local or general phenomena of hunger, the existence of which was rendered probable by this theory? This point of physiology is one of those in which the want of direct experiment is the most strongly felt. The pressure and contraction of the stomach are considered amongst the local phenomena of hunger: "the sides of that viscus," it is said, "become thicker; it changes its form and situation, and draws the duodenum a little towards it; its cavity contains saliva mixed with air, mucosities, bile, which has regurgitated in consequence of the dragging of the duodenum; the quantity of these humours increases in the stomach in proportion as hunger is of longer continuation. The cystic bile does not flow into the duodenum; it collects in the gall-bladder, and it becomes abundant and black according to the continuance of abstinence. A change takes place in the order of the circulation of the digestive organs; the stomach receives less blood, perhaps on account of the flexion of these vessels which is then greater; perhaps by the compression of the nerves, in consequence of this confinement, the influence of which upon the circulation will then be diminished. On the other hand, the liver, the spleen, the epiploon, receive more, and perform the office of *diverticula:* the liver and the spleen, because they are less supported when the stomach is empty, and then present a more easy access to the blood; and the epiploon, because the vessels are then less *flexuous,*" &c.* The most of these data are mere conjectures, and nearly devoid of proof; they have been already, in part, refuted by Bichât, but some of the objections of this ingenious physiologist are not entirely free from error themselves. Not being able to enter into the details of this discussion here, I will only mention the observations that I have made in this respect. After twenty-four, forty-eight, and even sixty hours of complete abstinence, I have never seen the contraction and pressure of the stomach of which these authors speak: this organ has always presented to me very considerable dimensions, particularly in its splenic extremity; it was only after the

Local phenomena of hunger.

Observations upon the state of the stomach during hunger.

* Diction. des Sciences Med. Art. Digestion.

fourth and fifth day that it appeared to return upon itself, to diminish much in size, and slightly in position; even these effects are not strongly marked unless fasting has been very strictly observed.

Observation upon the pressure supported by the abdominal viscera during hunger.

Bichât thinks that the pressure sustained by the empty stomach is equal to that which it supports when distended by aliments, since, says he, the sides of the abdomen are compressed in proportion as the volume of the stomach diminishes. The contrary of this may be easily proved by putting one or two fingers into the abdominal cavity after having made an incision in its sides; it will then be easily seen that the pressure sustained by the viscera, is in a certain degree, in direct proportion to the distension of the stomach; if the stomach is full, the finger will be strongly pressed, and the viscera will press outward to escape through the opening; if it is empty, the pressure will be very trifling, and the viscera will have little tendency to pass out from the abdominal cavity. It must be understood that in this experiment the pressure exerted by the abdominal muscles, when they are relaxed, ought not to be confounded with that which they exert when contracted with force. Thus, when the stomach is empty, all the reservoirs contained in the abdomen are more easily distended by the matters which remain some time in them. I believe this is the principal reason why bile then accumulates in the gall-bladder. With regard to the presence of bile in the stomach, that some persons regard as the cause of hunger, I believe, unless in certain sickly cases, that bile does not enter it, though it continues to flow into the small intestine, as I have ascertained by experiment.

The quantity of mucus that the cavity of the stomach presents is so much greater in proportion to the prolongation of abstinence. My experiments on this point agree entirely with that of Dumas.

Relatively to the quantity of blood which goes to the stomach when empty, in proportion to the volume of its vessels, and the mode of circulation which then exists, I am tempted to believe that it receives less of this fluid than when it is full of aliments; but, far from being in this respect in opposition with the other abdominal organs, this disposition appears to be common to all the organs contained in the abdomen.

General phenomena of hunger.

To the general phenomena of hunger is ascribed a weakness and diminution of the action of all the organs;

the circulation and the respiration become slow, the heat of the body lowers, the secretions diminish, the whole of the functions are exerted with more difficulty. The absorption alone is said to become more active, but nothing is strictly demonstrated in this respect.

Feelings that ought not to be confounded with hunger.

Hunger, appetite itself, which is only its first degree, ought to be distinguished from that feeling which induces us to prefer one sort of food to another, from that which causes us, during a repast, to choose one dish rather than another, &c.

These feelings are very different from real hunger, which expresses the true wants of the economy; they in a great measure depend on civilization, on habits and certain ideas relative to the properties of aliments. Some of them are in unison with the season, the climate, and then they are equally legitimate as hunger itself; such is that which inclines us to a vegetable regimen in hot countries, or during the heats of summer.

Causes that render hunger more intense.

Certain circumstances render hunger more intense, and cause it to return at nearer intervals: such as a cold and dry air, winter, spring, cold baths, dry frictions upon the skin, exercise on horseback, walking, bodily fatigue, and generally all the causes that put the action of the organs in play, and accelerate the nutritive process with which hunger is essentially connected. Some substances, being introduced into the stomach, excite a feeling like hunger, but which ought not to be confounded with it.

There are causes which diminish the intensity of hunger, and which prolong the periods at which it habitually manifests itself: amongst this number are the inhabiting of hot countries, and humid places, rest of the body and mind, depressing passions, and indeed all the circumstances that interrupt the action of the organs, and diminish the activity of nutrition. There are also substances which, being brought into the digestive canals, prevent hunger, or cause it to cease, as opium, hot drinks, &c.

Proximate cause of hunger.

What has not been said upon the causes of hunger? It has been, by turns, attributed to the providence of the vital principle, to the frictions of the sides of the stomach against each other, to the dragging of the liver upon the diaphragm, to the action of bile upon the stomach, to the acrimony and acidity of the gastric juice, to fatigue of the contracted fibres of the stomach, to compression of the nerves of this viscus, &c., &c.

Hunger arises, like all other internal sensations, from the action of the nervous system; it has no other seat than this system itself, and no other causes than the general laws of organization. What very well proves the truth of this assertion is, that it sometimes continues though the stomach is filled with food; that it cannot be produced though the stomach has been some time empty; lastly, that it is so subject to habit as to cease spontaneously after the habitual hour of repast is over. This is true not only of the feeling which takes place in the region of the stomach, but also of the general weakness that accompanies it, and which, consequently, cannot be considered as real, at least in the first instant in which it is manifested.

Many authors confound hunger with the effects of a complete abstinence continued till death supervenes: we will not follow their example. Hunger, considered as an instinctive phenomenon, belongs to physiology; considered as the cause of disease, it belongs no more to this science, but to *semeiotics*.

Of Thirst.

Of thirst. The desire of drinking is called *thirst*. It is variable according to individuals, and it is rarely uniform in the same person. Generally speaking, it consists of a feeling of dryness, of heat and constriction, which reigns in the back part of the mouth, the pharynx, œsophagus, and sometimes the stomach. Though thirst continue but for a short time, these parts swell and become red, the mucous secretion ceases almost entirely; that of the follicles changes, becomes thick and tenacious; the flowing of the saliva diminishes, and its viscosity is sensibly augmented.

These phenomena are accompanied by a vague inquietude, by a general heat; the eyes become red, the mind is troubled, the motion of the blood is accelerated, the respiration becomes laborious, the mouth is frequently opened wide, in order to bring the external air into contact with the irritated parts, and thus to produce a momentary ease.

Causes of thirst. For the most part the inclination to drink is developed, when by some cause, for example, heat and dryness of the atmosphere, the body has lost a great deal of fluid; but it appears under a great many different circumstances, such as having spoken long, having eaten certain sorts of food, or swallowed a substance which remains in the œsophagus, &c. The vicious habit of frequently drinking, and the desire of tasting some liquids, such as brandy, wine, &c., cause the development of a feeling which has the greatest analogy with thirst.

There are people who have never felt thirst, who drink from a sort of sympathy, but who could live a long time without thinking of it, or without suffering from the want of it; there are other persons in whom thirst is often renewed, and becomes so strong as to make them drink from forty to sixty pints of liquid in twenty-four hours; in this respect great individual differences are remarked.

Let us, with some authors, go back to the proximate cause of thirst. Shall we say that it is the effect of the providence of the soul? Will we place its seat in the nerves of the pharynx, in the blood vessels or in the lymphatic vessels? These considerations ought, henceforward, to find a place only in the history of physiology. Thirst is an internal sensation, an instinctive feeling; it belongs essentially to the organization, and admits of no explanation.

Neither will we notice the morbid phenomena which accompany and precede death by the complete privation of drink; this study belongs entirely to pathological physiology.

Of the Digestive Organs in particular.

Of the digestive organs in particular.

The digestive actions which by their union constitute digestion, are—1st, the apprehension of aliments; 2d, mastication; 3d, insalivation; 4th, deglutition; 5th, the action of the stomach; 6th, the action of the small intestines; 7th, the action of the large intestines; 8th, the expulsion of the *fecal* matters.

All the digestive actions do not equally contribute to the production of chyle; the action of the stomach and that of the small intestines, are alone absolutely necessary.

The digestion of solid food requires generally the eight digestive actions; that of drinks is much more simple; it comprehends only apprehension, deglutition, the action of the stomach, and that of the small intestine.

We shall first treat of the digestion of the aliments, and afterwards of that of the drinks.

Of the apprehension of Solid Food.

Of the taking of solid food.

The organs for taking in food are the superior extremities and the mouth. We have spoken elsewhere of the superior extremities; we will say a few words of the different parts which constitute the mouth.

Organs of the taking of solid food.

With anatomists, the mouth is the oval cavity formed above, by the palate and the upper jaw; below, by the tongue and the lower jaw; on the sides, by the cheeks; behind, by the *velum* of the palate and the pharynx; and in front by the lips.

The dimensions of the mouth are variable in different persons, and are susceptible of an enlargement in every direction; downwards, by lowering the tongue and separating the jaws; transversely, by the distension of the cheeks, and from the front backward, by the motion of the lips, and of the *velum* of the palate.

The jaws determine most particularly the form and dimensions of the mouth; the superior jaw makes an essential part of the face, and moves only along with the head; on the contrary, the inferior possesses a very great mobility.

Of the teeth.

The jaws are furnished with small, very hard bodies, called teeth; they are generally considered as bones, but they are very different in many respects, and particularly in that of structure, in the mode of formation, in their uses, in their unchangeableness from contact with the air; but they are like bones in respect of their hardness and chemical composition.

Every one knows that there are three sorts of teeth; the incisors, which fill the anterior part of the jaws; the grinders, which fill the posterior part; and the eye teeth, which are placed between the incisors and the grinders.

There are two parts distinguished in the teeth; the one exterior; the other contained in the jaws. These two parts are differently disposed. The exterior having particular uses in each species of teeth, has a variable form. It is cubic in the grinders, conical in the eye teeth, wedge-like in the incisors. Whatever be the form, its hardness is very great; it wears with time like inert bodies, that undergo repeated frictions.

Roots of the teeth.

The roots having one common use in the three sorts, that of forming the junction of the teeth with the jaws, and transmitting to them the very great efforts which the teeth sometimes support, they ought to have, and, in fact, have one common form. They are received into cavities called sockets; they fill them exactly. The sides of these cavities appear to exert a considerable pressure upon the roots of the teeth; we may at least suppose so, for these cavities press in upon each other, and become obliterated when they contain no root of the teeth, or something which has the same form and resistance. Sockets.

The incisors and the eye teeth have only one root; the grinders have generally several. But whatever is their number, the roots have always the form of a cone, the base of which corresponds to the exterior, and the top to the bottom of the socket; in certain cases they present curves more or less marked.

The edge of the socket is covered with a thick layer, fibrous, resisting, denominated gum. This layer surrounds exactly the inferior part of the teeth, adheres forcibly to them, and adds to the solidity of the junction of the teeth with the jaws. It is capable of supporting a very strong pressure without inconvenience: we will see the advantages that result from this disposition. Gums.

We ought to consider in the parts that contribute to the apprehension of aliments, the muscles that move the jaws, and particularly the inferior. The same thing takes place with the tongue, the numerous motions of which have a great influence on the dimensions of the mouth.

Mechanism of the apprehension of Food.

Nothing is simpler than the taking in of aliments; it consists in the introduction of alimentary substances into the mouth. For this purpose the hands seize the aliments and divide them into small portions susceptible of being contained in the mouth, and introduce them into it either directly or by means of proper instruments.

But, in order to their being received into this cavity the jaws must separate, in other words, the mouth opens.—Now, there have been long discussions in order to know, if, in the opening of the mouth, the lower jaw alone moves, or if the two jaws move at the same time. Without entering into this inquiry, which perhaps does not deserve all the importance which is attached to it, we shall merely observe, that it is easily seen that the lower jaw alone moves when the mouth is opened in an ordinary manner. When it is opened widely, the upper jaw is raised, that Separation of the jaws.

is, the head is slightly thrown back upon the vertebral column: but in every case the inferior jaw is always that whose motions are most extended, at least if no physical object is opposed to it. In this case the opening of the mouth depends solely upon the throwing back the head upon the vertebral column, or, what is the same thing, on the elevation of the superior jaw.

Action of the incisors.

In many cases, when the food is introduced into the mouth, the jaws come together to retain it, and assist in mastication, or deglutition; but frequently the elevation of the inferior jaw contributes to the taking of the food. We have an example of it when one bites into fruit: then the incisors are thrust into the alimentary substance in opposite directions, and, acting as the blades of scissors, they detach a portion of the mass.

This motion is produced, principally by the contraction of the elevating muscles of the lower jaw, which represents a lever of the third kind, the *power* of which is at the insertion of the elevating muscles, the *point of support* at the *temporo-maxillary* articulation, and the *resistance* in the substance upon which the teeth act. The volume of the body placed between the incisors has an influence upon the force by which it may be pressed. If it is small the power will be much greater, for all the elevating muscles are inserted perpendicularly to the jaw, and the whole of their force is employed in moving the lever that it represents; if the volume of the body is such that it can hardly enter the mouth, though it presents very little resistance, the incisors will not enter it, for the *masseter*, the temporal, and the internal *pterygoid* muscles, are inserted very obliquely into the jaw, whence results the loss of the greater part of the force that they develop in contracting.

Manner of assisting the teeth with the hand.

When the efforts of the muscles of the jaws are not sufficient to detach a portion of the alimentary mass, the hand so acts upon it as to separate it from the portion retained by the teeth. On the other hand, the posterior muscles of the neck draw the head strongly back, and from the combination of these efforts results the separation of a portion of the food which remains in the mouth. In this mode the incisors and eye teeth are generally employed; the grinders are rarely used.* By the succes-

* In carnivorous animals, which frequently employ this mode of apprehension, all the three species, but chiefly the canine teeth, contribute to its performance.

sion of these motions of taking food the mouth is filled, and on account of the suppleness of the cheeks, and the easy depression of the tongue, a considerable quantity of food may be accumulated in it. Accumulation of the food in the mouth.

When the mouth is full, the *velum* of the palate is lowered, its inferior edge is applied upon the most distant part of the base of the tongue, so that all communication is intercepted between the mouth and the pharynx.

Mastication and Insalivation of the Food.

Independently of what we have said of the mouth, in respect to taking the food, to conceive its uses in mastication and insalivation, it is useful to remark that fluids abound in the mouth proceeding from different sources. First, the mucous membrane which covers its sides secrete an abundant mucosity; numerous isolated, or agglomerated follicles that are observed in the interior of the cheeks, at the junction of the lips with the gums, upon the back of the tongue, on the anterior aspect of the *velum* and the uvula, pour continually the liquid that they form into the internal surface of the mouth. The same thing takes place with mucous glands, which exist in great number in the interior of the cheeks and palate. Fluids poured into the mouth.

Lastly, there is poured into the mouth the saliva secreted by six glands, (64) three on each side, and which bear the name of *parotid*, *sub-maxillary*, and *sub-lingual*. The first, placed between the external ear and the jaw, have each a secreting canal which opens on the level of the second small superior grinder; each maxillary gland has one which terminates on the sides of the ligaments of the tongue, near which those of the sub-lingual glands open.

These fluids are probably variable in their physical and chemical properties according to the organs by which they are formed; but the distinction has not yet been established by chemistry by direct experiments: the mixture under the name of saliva has been exactly analyzed.* Of the saliva.

* See secretion of saliva.

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(64) The case of H. R—ss proves clearly that the saliva flows in consequence of a sympathy subsisting between the glands which secrete it, and the stomach. (See page 145.)

Amongst the alimentary substances deposited in the mouth, the one sort only traverse this cavity without suffering any change; the others, on the contrary, remain a considerable time in it, and undergo important modifications. The first are the soft sorts of food, or nearly liquid, of which the temperature is little different from that of the body; the second are the aliments, which are hard, dry, fibrous, and those whose temperature is more or less different from what is proper for the animal economy. They are both in common, however, appreciated by the organs of taste in passing through the mouth.

Changes that the food undergoes in the mouth.

We may attribute to three principal modifications the changes that the food undergoes in the mouth: 1st, change of temperature; 2d, mixture with the fluids that are poured into the mouth, and sometimes dissolution in these fluids; 3d, pressure more or less strong, and very often division, which bruising destroys the cohesion of their parts. It is besides easily and frequently transported from one part of this cavity to another. These three modes of change do not take place successively, but simultaneously, by mutually favouring each other.

Change of temperature.

The change of temperature of the food retained in the mouth is evident; the sensation which it excites in it is sufficient to prove this. If it has a low temperature, it produces a vivid impression of cold, which continues until it has absorbed the caloric necessary to bring it near to the temperature of the sides of the mouth; the contrary takes place if the temperature is higher than that of the mouth.

It is the same with our judgment on this occasion, as with that which relates to the temperature of bodies which touch the skin; we join to it, unknown to us, a comparison with the temperature of the atmosphere and with that of the bodies which have been previously in contact with the mouth; so that a body preserving the same degree of heat will appear to us alternately hot or cold, according to the temperature of the bodies formerly in the mouth.

The change of temperature that the food undergoes in the mouth is only an accessary phenomenon; their trituration and their mixture more or less intimate with the fluids poured into this cavity, are what merit particular attention.

As soon as an aliment is introduced into the mouth, it is pressed by the tongue, applying it against the palate, or against some other part of the sides of the mouth. If the aliment is soft, if its parts cohere but little, this simple pressure is enough to break it; if the alimentary substance is composed of liquid and solid, the liquid is expressed by this pressure, and the solid part only remains in the mouth. The tongue produces the effect, of which we speak, so much better in proportion as its membrane is muscular, and as a great number of muscles are destined to move it. Pressure of the tongue against the mouth.

It might astonish us that the tongue which is so soft could be capable of breaking a body offering even small resistance; but, on the one hand, it hardens in contracting, like all the muscles, and, besides, it presents under the mucous membrane which covers its superior aspect, a dense and thick fibrous layer.

Such are the phenomena that take place if the food has but little resistance; but if it presents a considerable resistance it then undergoes the action of the masticating organs.

The essential agents of mastication are the muscles that move the jaws, the tongue, the cheeks and the lips: the *maxillary* bones and the teeth serve only as simple instruments. Organs of mastication.

Though the motions of both jaws may contribute to mastication, it is produced almost always by those of the inferior one. This bone may be lowered, raised, and pressed strongly against the upper jaw; carried forward, backward, and even directed a little towards the sides. These different motions are produced by the numerous muscles which are attached to the jaw.

But the jaws could never have produced the necessary effect in mastication if they had not been furnished with teeth, the physical properties of which are particularly suited to this digestive action.

Some remarks upon these bodies are necessary for the knowledge of what follows.

The grinders are those which serve the most to bruise the food; they are twenty in number, ten in each jaw, five on the right and five on the left. The form of their crown is that of an irregular cube; the surface by which they correspond, is bristled with pyramidal asperities, variable in number according as they are examined in the anterior or *small*, or in the posterior or *large grinders*. These asperities are so disposed, that those of the superior teeth easily grind against those of the inferior, and *vice versa.*

In the inferior part and centre of the crown of the tooth, there exists a cavity filled by the organ which secreted the tooth in childhood. There is a canal in the root, traversed by an artery, a nervous filament, and a vein, all destined to the bulb of the tooth.

Remarks upon the teeth.

The substance which forms the teeth is of an excessive hardness, particularly the exterior layer, or *enamel;* this disposition is very necessary. Destined to bruise bodies whose hardness is sometimes very great, it was necessary that they should present a proportional hardness; besides, as they perform this office during the whole of life, or nearly, it was necessary that they should wear but slowly. In this last respect their extreme hardness was indispensable; for no bodies, however hard they are, can bear repeated frictions without being worn; and those bodies whose hardness is less, ought, with equal friction, to be worn down with greater rapidity.

Chemical composition of the teeth.

The matter which forms the body and root of the teeth appears homogeneous in all its parts; on the contrary, the enamel which covers the crown, presents fibres very adherent to each other, and disposed, for the most part, perpendicularly to the surface of the tooth. Human teeth are formed almost entirely of carbonate and phosphate of lime; in 100 parts, 99.5 consist of these salts; the remainder is of animal matter.* (65) The enamel is almost entirely void of it: its whiteness and great hardness ought to be attributed to this cause.

We have already shown how very solid is the articulation of the teeth with the jaws; the grinders, on account of their use, ought to present an articulation still more

* Experiments have taught me, that the proportion of animal matter is considerably greater in herbivorous, and still more in carnivorous animals. Of the three, herbivorous animals have in their teeth the largest proportion of carbonate of lime.

(65) Our author must surely be mistaken in his quotation of animal matter here. Pepys makes the cartilage 20 per cent., and in this he coincides with M. Hatchet, Phil. Trans. 1799, p. 328. A tooth macerated in acid till nothing more is given out, still retains its original size;—doubtless a cartilage of this bulk must have a more considerable weight than that assigned to it in the text.

solid: they have also many roots, or if they have only one it is larger. For the rest, whether they are single or more numerous, their form is conical, and they are received into sockets of the same form. Every root is like a wedge driven into the jaw.

The whole of the teeth, proper to each jaw, form what is called in anatomy the *alveolar arches*.

The form of these arches is semiparabolic; the inferior is a little larger than the superior; the inferior aspect of the latter is a little inclined outwards, whilst the superior aspect of the inferior is turned inwards. These surfaces present in the part formed by the grinders a central furrow, bordered by two rows of eminences. When the jaws are placed together, the inferior incisors and eye teeth are placed partly behind the superior; the salient external edge of the inferior alveolar arch enters into the furrow of the superior. In the circumstances in which the incisors meet upon their edges there remains an interval between the *molares*.

To add to the solidity of the junction of the teeth with the jaws, nature has so disposed them that they almost all touch by their sides, which present a particular surface for this purpose. It results from this disposition, that when one tooth supports any effort whatever, a part of it is sustained by the whole arch to which it belongs.

These facts being known, it is easy to conceive the explanation of the mechanism of mastication.

Mechanism of Mastication.

Mechanism of mastication.

For the commencement of mastication the inferior jaw must be lowered, an effect which is produced by the relaxation of its elevating, and the contraction of its depressing muscles. The food must then be placed between the dental arches, either by the tongue or some other agent; the inferior jaw is then raised by the *masseter*, *internal pterygoid*, and *temporal* muscles, the intensity of whose contraction depends upon the resistance of the food. This being pressed between two unequal surfaces whose asperities fit into each other, is divided into small portions, the number of which is in proportion to the facility with which they have given way.

But a motion of this kind reaches only a part of the food contained in the mouth, and it must be all equally divided. This takes place by the successive motions of the inferior jaw, and by the contraction of the muscles of the cheeks, of those of the tongue and lips, which bring the food between the teeth successively and promptly during the separation of the jaws, that it may be bruised when they come together.

Mastication of food.

When the alimentary substances are soft and easily bruised, two or three masticatory motions are sufficient to divide all that is in the mouth; the three kinds of teeth are employed in it. A longer continued mastication is necessary when the substances are more resisting, fibrous or tough: in this case we chew only with the *molares*, and often only with one side at a time, to allow the other to rest. In employing the grinders there is an advantage of shortening the arm of the lever represented by the jaw, and by so doing of rendering it more advantageous for the power that moves it.

Transmission of the efforts of the teeth to the jaws

In the mastication, the teeth have sometimes to support very considerable efforts, which would inevitably shake, or else displace them, were it not for the extreme solidity of their articulation with the jaws. Each root acts like a wedge, in transmitting to the sides of the sockets the force by which it is pressed.

The advantage of the conical form of the roots is not doubtful. By reason of this form, the force by which the tooth is pressed, and which tends to thrust it into the jaw, is decomposed; one part tends to separate the sides of the sockets, the other to lower them; and the transmission, instead of being carried to the extremity of the root, which could not have failed to take place in a cylindric form, is distributed over all the surface of the socket. The grinders that have more considerable efforts to sustain, have a number of roots, or at least one very large. The incisors and eye teeth, that have only one small root, have never any great pressure to support.

If the gums had not presented a smooth surface and a dense tissue, placed as they are round the neck of the teeth and filling their intervals, they would have been torn every instant; for, in the mastication of hard and irregular substances, they are constantly exposed to the pressure of their edges and angles. This inconvenience happens whenever their tissue becomes soft, as in scorbutic affections.

During the time of mastication the mouth is shut behind by the curtain of the palate, the anterior surface of which is pressed against the base of the tongue; the food is retained before by the teeth and the lips. Use of the velum of the palate in mastication.

Insalivation of the Aliments.

Whenever we have an appetite, the view of food determines a considerable afflux of saliva into the mouth; in some people it is so strong as to be projected to the distance of several feet. I have at present before my eyes an example of this kind. The presence of food in the mouth keeps up and excites this abundant secretion.

Whilst the aliments are bruised and triturated by the masticating organs, they imbibe, and are penetrated completely by the fluids that are poured into the mouth, and particularly by the saliva. It is easy to conceive that the division of the food and the numerous displacements that it suffers during mastication, singularly favour its mixture with the mucous and salivary juices. Insalivation of food.

Most of the alimentary substances submitted to the action of the mouth are dissolved or suspended wholly or in part in the saliva, and immediately they become proper for being introduced into the stomach, and are forthwith swallowed.

On account of its viscosity, the saliva absorbs air, by which it is swept in the different motions necessary for mastication; (66) but the quantity of air absorbed in this circumstance is inconsiderable, and has been generally exaggerated. Utility of mastication and insalivation of food.

Of what use is the trituration of food and its mixture with the saliva? Is it a simple division which renders the aliments more proper for the alterations which they undergo in the stomach, or do they suffer the first degree

(66) The saliva, from the mucus it contains, absorbs oxygen from the atmosphere; but the air here alluded to is held imprisoned in the bubbles formed in the saliva by the motion of the tongue and cheeks, and whose viscidity prevents their thin walls from collapsing. This is the foam or froth seen in the mouth of irritated animals or men: also in epilepsy, apoplexy, loud babbling speakers, or where the tongue is too large for the mouth. In idiots, the saliva flows out of the mouth, but it is seldom spumous, except when they are excited. The mere champing of the bit forms it in the horse.

of animalization in the mouth? on this point there is nothing certain known.

Let us remark that mastication and insalivation change the savour and odour of the food; that mastication, sufficiently prolonged, generally renders digestion more quick and easy; that on the contrary, people who do not chew their food have often on this account very painful and slow digestion.

In what manner we know that mastication and insalivation are carried sufficiently far.

We are informed that mastication and insalivation are carried sufficiently far by the degree of resistance and savour of the food; besides, the sides of the mouth being endowed with *tact*, and the tongue with a real sense of *touch*, they are very capable of appreciating the physical changes which the food undergoes.

By some authors this office is attributed to the *uvula*;* I doubt their opinions, for its situation has no relation with the food during mastication. I have often observed persons who had lost the uvula altogether, either by a venereal ulcer, or by excision, and I have never remarked that their mastication suffered the least derangement, nor that they swallowed improperly.

Of the Deglutition of Aliments.

Deglutition.

Deglutition is understood to be the passage of a substance, either solid, liquid, or gaseous, from the mouth to the stomach. Deglutition of the solid food is the only kind that will occupy us at present. Though deglutition is very simple in appearance it is nevertheless the most complicated of all the muscular actions that serve for digestion. It is produced by the contraction of a great number of muscles, and requires the concurrence of many important organs.

Apparatus of deglutition.

All the muscles of the tongue, those of the *velum* of the palate, of the pharynx, of the larynx, and the muscular layer of the œsophagus are employed in deglutition. If we wish to acquire an accurate idea of this act we ought to have an exact and detailed account of it. The nature of this work will not suffer us to give anatomical details of

* It is, they affirm, a *vigilant sentinel*, and judges of the instant when the bolus can be transmitted with impunity; it keeps the organs of deglutition and the stomach *on the alert*, and *disposes* them to receive or reject the aliment presented.

this kind; we will present only some observations upon the *velum* of the palate, the pharynx, and the œsophagus.

Of the velum of the palate.

The *velum* is a sort of valve attached to the posterior edge of the roof of the palate; its form is nearly quadrilateral; its free or inferior edge is pointed and forms the *uvula*. Like the other valves of the intestinal canal, the *velum* is essentially formed by a duplicature of the digestive mucous membrane; there are many mucous follicles that enter into its composition, particularly in the uvula. Eight muscles move it: it is raised by the two internal *pterygoid;* the external *pterygoid* hold it transversely; the two *palato-pharyngei*, and the two *constrictores isthmi faucium* carry it downwards. These four are seen at the bottom of the throat, where they raise the mucous membrane, and form the pillars of the *velum* of the palate, between which are situated the *amygdalae*, a mass of mucous follicles. The opening between the base of the tongue below, the *velum* of the palate above, and the pillars laterally, is called the isthmus of the throat. By means of this muscular apparatus the *velum* of the palate may have many changes of position. In the most common state it is placed vertically, one of its faces is anterior, the other posterior; in certain cases it becomes horizontal: it has then a superior and inferior aspect, and its free edge corresponds to the concavity of the pharynx. This last position is determined by the contraction of the elevating muscles.

Bichât asserts that the elevation of the *velum* may go so far as to apply it against the opening of the posterior nostrils: this motion appears impossible; there is no muscle so disposed as to produce it, and the position of the pillars evidently opposes it. The lowering of the *velum* is produced by the contraction of the muscles that form the pillars. We have already noticed that these motions in most persons do not depend on the will.

Of the pharynx.

The pharynx is a vestibule into which open the nostrils, the *Eustachian tubes*, the mouth, the larynx and the œsophagus, and which performs very important functions in the production of voice, in respiration, hearing and digestion.

The pharynx extends from top to bottom, from the *basilar* process of the occipital bone, to which it is attached, to the level of the middle part of the neck.

Its transverse dimensions are determined by the os hyoides, the larynx and the *pterygo-maxillary aponeurosis*, to which it is fixed. The mucous membrane which covers it interiorly, is remarkable for the development of its veins, which form a very apparent plexus. Round this membrane is the muscular layer, the circular fibres of which form the three constrictor muscles of the pharynx, the longitudinal fibres of which are represented by the *stylo pharyngeus* and *constrictores isthmi faucium*. The contractions of these different muscles are not generally subject to the will.

Of the œsophagus

The œsophagus is the immediate continuation of the pharynx, and is prolonged as far as the stomach, where it terminates. Its form is cylindrical; it is united to the surrounding parts by a slack and extending cellular tissue, which gives way to its dilatation and its motions. To penetrate into the abdomen the œsophagus passes between the pillars of the diaphragm, with which it is closely united. The mucous membrane of the œsophagus is white, thin and smooth; it forms longitudinal folds very proper for favouring the dilatation of the canal. Above it is confounded with that of the pharynx. Doctor Rullier has lately called the attention of anatomists to the lower part, which forms many denticulations terminated by a fringed border, hanging free in the cavity of the stomach.*

There are found in it a great number of mucous follicles, and at its surface there are perceived the orifice of many excretive canals of the mucous glands.

The muscular layer of the œsophagus is thick, its tissue is denser than that of the pharynx; the longitudinal fibres are the most external and the least numerous; the circular are placed in the interior and are very numerous.

Round the pectoral and inferior portion of the œsophagus the two nerves of the eighth pair form a plexus which embraces the canal, and sends many filaments into it.

The contraction of the œsophagus takes place without the participation of the will.

* In man, the difference between the mucous membrane of the œsophagus and of the stomach is as striking as that which exists between the splenic and pyloric portions of the same membrane in the horse.

Mechanism of Deglutition.

To facilitate its study we divide deglutition into three periods. In the first the food passes from the mouth to the pharynx; in the second it passes the opening of the glottis, that of the nasal canals, and arrives at the œsophagus; in the third it passes through this tube and enters the stomach.*

Division of the deglutition into three periods.

Let us suppose the most common case, that in which we swallow at several times the food which is in the mouth, and according as mastication takes place.

First period of deglutition.

As soon as a certain quantity of food is sufficiently chewed, it is placed, by the effects of the motions of mastication, in part upon the superior face of the tongue, without the necessity, as some think, of its being collected by the point of the tongue from the different parts of the mouth. Mastication then stops; the tongue is raised and applied to the roof of the palate, in succession, from the point towards the base. The portion of food, or the *alimentary bolus* placed upon its superior surface, having no other way to escape from the force that presses, is directed towards the pharynx; it soon meets the *velum* of the palate applied to the base of the tongue and raises it; the *velum* becomes horizontal, so as to make a continuation of the palate. The tongue, continuing to press the food, would carry it towards the nasal canals, if the *velum* did not prevent this by the tension that it receives from the external peristaphyline muscles, and particularly by the contraction of its pillars; it thus becomes capable of resisting the action of the tongue, and of contributing to the direction of the food towards the pharynx.

The muscles which determine more particularly the application of the tongue to the top of the palate, and to the *velum* of the palate, are the proper muscles of the organ, aided by the *mylo-hyoideus*. Here the first time of deglutition terminates. Its motions are voluntary except those of the *velum* of the palate. The phenomena happen slowly and in succession; they are few and easily noticed.

phase or period

The second period is not the same: in it the phenomena are simultaneous, multiplied, and are produced with such promptitude, that Boerhaave considered them as a sort of convulsion.

Second period of deglutition.

* See my Thesis.—Paris, 1808.

The space that the alimentary bolus passes through in this time is very short, for it passes only from the middle to the inferior part of the pharynx; but it was necessary to avoid the opening of the glottis and that of the nasal canals, where its presence would be injurious. Besides, its passage ought to be sufficiently rapid in order that the communication between the larynx and the external air, may not be interrupted except for an instant.

Let us see how nature has arrived at this important result. The alimentary bolus no sooner touches the pharynx than every thing is in motion. First, the pharynx contracts, embraces and retains the bolus; the *velum* of the palate, drawn down by its pillars, acts in the same way. On the other hand, and in the same instant, the base of the tongue, the os hyoides, the larynx, are raised and carried forward to meet the bolus, in order to render its passage more rapid over the opening of the glottis. Whilst the os hyoides and the larynx are raised, they approach each other, that is, the superior edge of the thyroid cartilage engages itself behind the body of the os hyoides: the epiglottic gland is pushed back; the epiglottis descends, inclines downwards and backwards, so as to cover the entrance of the larynx. The cricoid cartilage makes a motion of rotation upon the inferior horns of the thyroid, whence it results that the entrance of the larynx becomes oblique downwards and backwards. The bolus slides along its surface, and being always pressed by the contraction of the pharynx and of the *velum* of the palate, it arrives at the œsophagus.

It is not long since the position that the epiglottis takes in this case was considered as the only obstacle opposed to the entrance of the food into the larynx, at the instant of deglutition; but I have shown by a series of experiments that this cause ought to be considered as only accessary. In fact, the epiglottis may be entirely taken away from an animal, without deglutition suffering any injury from it. What is the reason, then, that no part of the food is introduced into the larynx the instant that we swallow? The reason is this. In the instant that the larynx is raised and engaged behind the os hyoides, the glottis shuts with the greatest closeness. This motion is produced by the same muscles that press the glottis in the production of the voice; so that if an animal has the recurrents and nerves of the larynx divided, whilst the epiglottis is untouched, its deglutition is rendered very difficult, because the principal cause is removed which opposes the introduction of food into the glottis.*

Immediately after the alimentary bolus has passed the glottis, the larynx descends, the epiglottis is raised, and the glottis is opened to give passage to the air.

After what has been said, it is easy to conceive why the food reaches the œsophagus without entering any of the openings which end in the pharynx. The *velum* of the palate, which, in contracting, embraces the pharynx, protects the posterior nostrils and the orifices of the Eustachian tubes; the epiglottis, and particularly the motion by which the glottis shuts, preserves the larynx.

Thus, the second period of deglutition is accomplished; by the effects of which the alimentary bolus passes the pharynx, and is engaged in the superior part of the œsophagus. All the phenomena which concur in it take place simultaneously, and with great promptitude: they are not subject to the will; they are then different in many respects from the phenomena that belong to the first period.

Third period of the deglutition

The third period of deglutition is that which has been studied with the least care, probably on account of the situation of the œsophagus, which is difficult to be observed except in its cervical portion.

The phenomena which are connected with it are not complicated. The pharynx, by its contraction, presses the alimentary bolus into the œsophagus with sufficient force to give a suitable dilatation to the superior part of this organ. Excited by the presence of the bolus, its superior circular fibres very soon contract and press the food towards the stomach, thereby producing the distension of those more inferior. These contract in their turn, and the same thing continues in succession until the bolus arrives at the stomach. In the upper two-thirds of the œsophagus, the relaxation of the circular fibres follows immediately the contraction by which they displaced the alimentary bolus. It is not the same with the inferior third; this remains some moments contracted after the introduction of food into the stomach.

* I have seen two individuals who wanted the epiglottis entirely, yet performed deglutition without any difficulty. It is in ulceration of the glottis only, that deglutition becomes difficult.

It is a mistake to suppose that the alimentary bolus has a rapid passage along the œsophagus: in my experiments I have been struck with the slowness of its progression. Sometimes it is two or three minutes in reaching the stomach; at others it stops at different times and remains some time at each station. In other circumstances I have seen it rise from the inferior extremity of the œsophagus towards the neck, and descend again immediately. When an obstacle prevents its entrance into the stomach, this motion is frequently repeated before the food is thrown out again into the mouth. Has it not happened to every body to feel distinctly the food stop in the œsophagus, and to be obliged to take drink, in order to make it descend?

When the alimentary bolus is very large, its progression is still slower and more difficult. It is accompanied by a vivid pain, occasioned by the distension of the nervous filaments which surround the pectoral portion of the canal. Sometimes the bolus adheres, and occasions very grave accidents.

Professor Hallé observed, in a woman afflicted with a disease that permitted the interior of the stomach to be seen, that the arrival of a portion of food in this viscus was immediately followed by the formation of a sort of stuffing at the cardiacal orifice. This stuffing was produced by the displacement of the mucous membrane of the œsophagus, which pressed the contracted circular fibres of this canal down into the stomach.

Mucus favours deglutition.

All the extent of the mucous surface that the alimentary bolus passes in the three periods of deglutition is lubricated by an abundant mucosity. In the way that the bolus passes, it presses more or less the follicles that it meets in its passage, it empties them of the fluid that they contain, and slides more easily upon the mucous membrane. We remark that in those places where the bolus passes more rapidly, and is pressed with greater force, the organs for secreting mucus are much more abundant. For example, in the narrow space where the second period of deglutition takes place, there are found the tonsils, the fungous *papillae* of the base of the tongue, the follicles of the *velum* of the palate, and the *uvula*, those of the epiglottis, and the arytenoid glands. In this case the saliva and the mucosity fulfil uses analogous to those of the *synovia*.

The mechanism by which we swallow the succeeding mouthfuls of food does not differ from that which we have explained.

Influence of the will upon deglutition.

Nothing is more easy than the performance of deglutition, and, nevertheless, all the acts of which it is composed are beyond the influence of the will and of instinct. We cannot make an empty motion of deglutition. If the substance contained in the mouth is not sufficiently chewed, if it has not the form, the consistence, and the dimensions of the alimentary bolus, if the motions of mastication which immediately precede deglutition have not been made, we will frequently find it impossible to swallow it, whatever efforts we make. How many people do we not find who cannot swallow a pill, or medicinal bolus, and who are obliged to fall upon other methods to introduce it into the œsophagus?

To have an idea of the power of the will in deglutition we may make the following experiment upon ourselves.

Endeavour to execute five or six times in succession, the motions of deglutition, in which the saliva contained in the mouth may be swallowed: the first and second will be easy; the third will be more difficult, for there will be very little saliva remaining to be swallowed; the fourth will take place only after a certain time when the saliva is renewed in the mouth; lastly, the fifth and sixth will be impossible, because there will be no more saliva to swallow. We may also call to mind how very difficult deglutition is whenever the mouth and pharynx are dry, or nearly so.

Of the Abdomen.

The digestive actions which remain to be examined take place in the cavity of the abdomen, the disposition of which deserves to be studied with attention.

Of the abdomen.

The abdomen is the largest of the cavities of the body, and it is more capable than any other of augmenting its dimensions. It contains a great number of organs destined for important functions, such as generation, digestion, secretion of urine, &c.

Its sides are in a great measure muscular, and have a very marked action upon the organs it contains.

The form of the abdominal cavity is irregularly *ovoid.* On account of its considerable dimensions, and in order to give precision to the language, it is divided into several regions, each of which has a particular name.

Divisions of the abdomen.

To comprehend this division, which is purely arbitrary, we must suppose two horizontal planes, the one of which will cut the abdomen at the level of the crest of the *os ilium*, and the other at the height of the edge of the *false ribs*. The part of the abdomen placed below the first plane is called the *hypogastric region;* that which is above the second is called the *epigastric region*, and that contained between the two planes is named the *umbilical region*. Suppose now two other planes which, in place of being horizontal like the first, will be vertical, and which, beginning at the two sides of the head, descend towards the anterior and inferior *spines* of the *os ilium*, dividing the abdomen front to back: it is clear that each of the abdominal regions will be divided into three compartments, of nearly equal dimensions, one of which will be in the middle and two others lateral.

Epigastric. Hypochondriac. Umbilical. Lumbar. Hypogastric. Illiac regions.

The subdivisions are called by the following names: the middle part of the epigastric region is called *epigastrium*, and its lateral parts *hypocondres;* the middle part of the umbilical region is called *umbilical*, and the lateral divisions *lumbar regions*; lastly, the name of *hypogastrium* is given to the middle division of the hypogastric region, whilst its sides are called *iliac regions*.

By means of these arbitrary divisions, the position and the relations of the respective organs contained in the abdomen may be fixed with exactness; this result, which is useful in physiology, is still more so in medicine. Above, the abdomen is separated from the breast by the diaphragm, a muscle disposed in form of a vault, the contraction of which has a very great influence upon the position and the action of the muscles contained in the abdomen. The circumference of the diaphragm is attached to the *false ribs*, and the vertebral column. In its state of relaxation its centre rises to the level of the sixth or seventh *true rib:* the result of this is, that the instant the muscle is contracted with energy, it causes a very considerable diminution of the abdominal cavity, compresses all the organs that it contains, and distends the soft parts, that in other respects form its sides.

Sides of the abdomen.

The inferior part of the abdomen is formed by the pelvis, the immoveable bones of which support the weight of a part of the viscera, serve as an insertion to the muscles, and do not yield, except very rarely, to the variations of the capacity of the abdomen. It must be remarked that the space comprehended between the *coccyx*, the tuberosities of the *ischium*, and the *arch* of the *pubis*, is filled only with soft parts, and particularly by the *ischio-coccygeal* muscles, the *levator ani*, and the external sphincter.

In front, and laterally, the parietes are formed by the abdominal muscles. These muscles which, as we have already seen, contribute powerfully to the different motions and attitudes of the trunk, have also an action in digestion, generation, &c.

Amongst the muscles, those that are large and situated upon the sides are intended to compress the abdomen, and the viscera contained in it. The long muscles situated anteriorly, are generally opposed to the first. They resist their action, and they are capable, in certain cases, of augmenting the dimensions of the abdomen, and diminishing the pressure which the viscera support.

From the sternal appendix to the pubis there exists a fibrous cord, by the crossing of the aponeurosis of the abdominal muscles: it is the linea alba of anatomists; its uses will be explained elsewhere. The muscles that enter into the composition of the sides of the abdomen are generally directed by the will; but there are also other circumstances in which they enter instinctively into contraction, and then they have an energy superior to that which they exhibit in ordinary cases.

Action of the Stomach upon the Aliments.

Hitherto we have seen only the physical actions of the digestive organs upon the food; chemical alterations will now present themselves to our examination. In the stomach the food is transformed into a matter proper to animals, which is named *chyme;* but, before treating of the phenomena that its formation presents, we will say a few words of the stomach itself.

Of the Stomach.

The stomach is intermediary to the œsophagus and the duodenum; it occupies in the abdomen the *epigastrium*, and a part of the left *hypochondrium;* its form, though variable, is generally that of a conoid bent upon itself. Of the stomach.

The left half of the stomach has always larger dimensions than the right; and as these halves act a different part in the formation of the chyme, I think it useful to call the one the splenic part, because it is supported on the spleen, and the other part pyloric, because it is supported on the pylorus. These parts are most generally separated from each other by a particular contraction.

The stomach being intended for the accumulation of the food in its cavity, it is evident that its dimensions, its situation in the abdomen, and its relations with the neighbouring organs, ought to suffer great variations.

Orifices of the stomach. This organ has two orifices; the one corresponds to the œsophagus; it is the cardiac or *œsophagean* orifice; the other communicates with the small intestine; it is called the intestinal orifice, or *pylorus*.

Structure of the stomach. The three membranes, or tunics that compose the stomach, present the most favourable dispositions for the variations of volume necessary to that organ.

The most exterior, or *peritoneal*, is formed of two plates which adhere very little to the viscera; it is continued without uniting along their sides, where they form the *omenta*, the extent of which is consequently in an inverse ratio to the volume of the stomach.

The mucous membrane of the stomach is of a whitish red, and marbled; it presents a great number of irregular folds, situated along the inferior and superior borders of the organ; they are also seen at its splenic extremity: they are more numerous and marked, in proportion as the stomach is more pressed together. No part of the mucous digestive membrane presents *villosities* so abundant and fine as that of the stomach. It is commonly covered with a mucous matter adhering to its surface, particularly in the splenic extremity. It contains many follicles, but it is necessary to remark that they are very abundant in the *pyloric* portion; there are a certain number seen near the *cardiac* orifice; they are very rare in the rest of the membrane.

Pyloric valve. At the pylorus, the mucous membrane forms a circular fold called the *pyloric valve*. A fibrous dense tissue is found between its plates, called by some authors the *pyloric muscle*.

The muscular layer of the stomach is very thin. Its circular and longitudinal fibres are separated from one another, particularly in the *splenic* part. This separation augments or diminishes with the volume of the stomach.

Vessels and nerves of the stomach.

Few of the organs receive so much blood as the stomach; four arteries, three of which are very considerable, are destined exclusively to it.

Its nerves are not less numerous; they are composed of the eighth pair, and a great many filaments proceeding from the *solar* plexus of the great sympathetic.

Accumulation of Food in the Stomach.

Accumulation of food in the stomach.

Before showing the changes that the food undergoes in the stomach, it is necessary to know the phenomena of their accumulation in this viscus, as well as the local and general effects that result from it.

The first mouthfuls of food swallowed are easily lodged in the stomach. This organ is not much compressed by the surrounding viscera; its sides separate easily and give way to the force which presses the alimentary bolus; but its distension becomes more difficult in proportion as new food arrives, for this is accompanied by the pressing together of the abdominal viscera, and the extension of the sides of the abdomen. This accumulation takes place particularly towards the right extremity and the middle part: the pyloric half gives way with more difficulty.

Whilst the stomach is distended, its form, its relations, and even its positions undergo alterations: in place of being flattened on its aspects, of occupying only the epigastrium and a part of the left *hypochondrium,* it assumes a round form; its great *cul de sac* is thrust into this *hypochondrium,* and fills it almost completely; the greater *curvature* descends towards the umbilicus, particularly on the left side; the pylorus, alone, fixed by a fold of the *peritoneum,* preserves its motion and its relations with the surrounding parts. On account of the resistance that the vertebral column presents behind, the posterior surface of the stomach cannot distend itself on that side: for that reason this viscus is wholly carried forward; and as the pylorus and the œsophagus cannot be displaced in this direction, it makes a motion of rotation, by which its great curve is directed a little forward; its posterior aspect inclines downwards, and its superior upwards.

Though it undergoes these changes of position and relation, it, nevertheless, preserves the recurved conoid form

Changes that take place in the abdomen by distension of the stomach.

which is proper to it. This effect depends on the manner in which the three tunics contribute to its dilatation. The two plates of the serous membrane separate and give place to the stomach. The muscular layer suffers a real distension; its fibres are prolonged, but so as to preserve the particular form of the stomach. Lastly, the mucous membrane gives way, particularly in the points where the folds are multiplied. It will be noticed that these are found particularly along the larger curve, as well as at the splenic extremity.

The dilatation of the stomach alone produces very important changes in the abdomen. The total volume of this cavity augments; the belly juts out; the abdominal viscera are compressed with greater force; often the necessity of passing urine, or feces, is felt. The diaphragm is pressed towards the breast, it descends with some difficulty; thence the motions of respiration, and the phenomena which depend on it, are more incommoded, such as speech, singing, &c.

In certain cases, the dilatation of the stomach may be carried so far that the sides of the abdomen are painfully distended, and respiration becomes difficult.

Influence of the contraction of the œsophagus on the distension of the stomach.

To produce such effects, the contraction of the œsophagus, which presses the food in the stomach, must be very energetic. We have remarked above the considerable thickness of the muscular layer of this canal, and the great number of nerves which go to it; nothing less than this disposition is necessary to account for the force with which the food distends the stomach. For more certainty, the finger has only to be introduced into the œsophagus of an animal by the cardiac orifice, and the force of the contraction will be found striking.

But if the food exerts so marked an influence upon the sides of the stomach and the abdomen, they ought themselves to suffer a proportionate reaction, and tend to escape by the two openings of the stomach. Why does this effect not take place? It is generally said that the cardia and pylorus shut; but I do not find that this phenomenon has been submitted to any particular researches. Here is what my own experiments have produced in this respect.

Cause which prevents the food from being

The alternate motion of the œsophagus prevents the return of the food into this cavity. The more the stomach is distended, contraction becomes the more intense and prolonged, and the relaxation of shorter duration. Its contraction generally coincides with the instant of inspiration, when the stomach is most forcibly compressed. Its relaxation ordinarily happens at the instant of expiration.

pressed back into the œsophagus.

We may have an idea of this mechanism by laying bare the stomach of a dog, and endeavouring to make the food pass into the œsophagus by compressing the stomach with both hands. It will be nearly impossible to succeed, whatever force is used, if it is done at the instant when the œsophagus is contracted: but the passage will take place, in a certain degree of itself, if the stomach is compressed at the instant of relaxation.

Cause why the food does not pass the pylorus.

The resistance that the pylorus presents to the passage of the aliments is of another kind. In living animals, whether the stomach is empty or full, this opening is habitually shut, by the constriction of its fibrous ring, and the contraction of its circular fibres. There is frequently seen another constriction in the stomach, at the distance of one or two inches, which appears intended to prevent the food from reaching the pylorus; we perceive, also, irregular and peristaltic contractions, which commence at the duodenum, and are continued into the pyloric portion of the stomach, the effect of which is to press the food towards the splenic part. Besides, should the pylorus not be naturally shut, the food would have little tendency to enter it, for it only endeavours to escape into a place where the pressure is less; and this would be equally great in the small intestine as in the stomach, since it is nearly equally distributed over all the abdominal cavity.

Other phenomena regarded as produced by the distension of the stomach.

Amongst the number of phenomena produced by the food in the stomach, there are several whose existence, though generally admitted, do not appear sufficiently demonstrated: such is the diminution of the volume of the spleen, and that of the blood-vessels of the liver, of the *omenta*, &c.; such is also a motion of the stomach, called by authors *peristole*, which should preside over the reception of the food, distribute it equally by exerting upon it a gentle pressure, so that its dilatation, far from being a passive phenomenon, must be essentially active. I have frequently opened animals whose stomachs were filled with food; I have examined the bodies of executed persons, a short time after death, and I have seen nothing favourable to these assertions.

Internal sensations which accompany the accumulation of food in the stomach.

The accumulation of food in the stomach is accompanied by many sensations, of which it is necessary to take account:—at first, it is an agreeable feeling, or the pleasure of a want satisfied. Hunger is appeased by degrees; the general weakness that accompanied it is replaced by an active state, and a feeling of new force. If the introduction of food is continued, we experience a sensation of fulness and satiety which indicates that the stomach is sufficiently replenished; and if, contrary to this instinctive information, we still persist to make use of food, disgust and nausea soon arrive, and they are very soon followed by vomiting. These different impressions must not be attributed to the volume of the aliments alone. Every thing being equal in other respects, food very nutritive occasions, more promptly, the feeling of satiety. A substance which is not very nourishing does not easily calm hunger, though it is taken in great quantity.

The mucous membrane of the stomach, then, is endowed with considerable sensibility, since it distinguishes the nature of substances which come in contact with it. This property is very strongly marked if an irritating poisonous substance is swallowed: intolerable pain is then felt. We also know that the stomach is sensible to the temperature of food.

We cannot doubt that the presence of the aliments in the stomach causes a great excitement, from the redness of the mucous membrane, from the quantity of fluid it secretes, and the volume of vessels directed there; but this is favourable to chymification. This excitement of the stomach influences the general state of the functions, as we will notice farther on.

The time that the aliments remain in the stomach is considerable, generally several hours; it is during this stay that they are transformed into chyme.

We will study the phenomena of this transformation, upon which we have only very incomplete data.

Changes of the Aliments in the Stomach.

It is more than an hour before the food suffers any apparent change in the stomach, more than what results from the perspiratory and mucous fluids with which they are mixed, and which are continually renewed.

The stomach is uniformly distended during this time; but the whole extent of the *pyloric* portion afterwards contracts, particularly that nearest the splenic portion, into which the food is pressed. Afterwards, there is nothing found in the pyloric portion but chyme, mixed with a small quantity of unchanged food.

But what is understood by chyme? The best authors have agreed to consider it as a homogeneous substance, pultaceous, greyish, of a sweetish taste, insipid, slightly acid, and preserving some of the properties of the food. This description leaves much to be explained. In fact, when has the chyme been seen with these characters? What sort of food was made use of? There is no mention made of this, and nevertheless it is a very important matter. Of the Chyme.

I thought that new experiments on this subject might be useful: I cannot consider here all the details of those I have made, but I will notice their most important results.

A. There are as many sorts of chyme as there are different sorts of food, if we judge by the colour, consistence, appearance, &c.; as we may easily ascertain, by giving different simple alimentary substances to dogs to eat, and killing them during the operation of digestion. I have frequently found the same result in man, in the dead bodies of criminals, or persons dead by accident. Experiments upon the formation of chyme.

B. Animal substances are generally more easily and completely changed than vegetable substances. It frequently happens that these last traverse the whole intestinal canal without changing their apparent properties. I have frequently seen in the rectum, and in the small intestine, the vegetables which are used in soup, spinage, sorrel, &c., which had preserved the most part of their properties: their colours alone appeared sensibly changed by the contact of the bile.

Chyme is formed particularly in the pyloric portion.—The food appears to be introduced slowly into it, and during the time they remain they undergo transformation. I believe, however, that I have observed frequent chymous matter at the surface of the mass of aliments which fill the splenic portion; but the aliments in general preserve their properties in this part of the stomach.

It would be difficult to tell why the pyloric portion is better adapted to the formation of chyme than the rest of the stomach; perhaps the great number of follicles that are seen in it modify the quantity or the nature of the Experiments upon the formation of chyme.

fluid that is there secreted. The transformation of alimentary substances into chyme takes place generally from the superficies to the centre. At the surface of portions of food swallowed, there is formed a soft layer easy to be detached. The substances seem to be attacked and corroded by a re-agent capable of dissolving them. The white of a hard egg, for instance, becomes in a little time as if plunged in vinegar, or in a solution of potass.

C. Whatever is the alimentary substance employed, the chyme has always a sharp odour and taste, and reddens paper coloured with turnsol.

Gas contained in the stomach during the formation of the chyme.

D. There is only a small quantity of gas found in the stomach during the formation of chyme; sometimes there exists none. Generally it forms a small bubble at the superior part of the splenic portion. Once only in the body of a criminal a short time after death, I gathered with proper precautions a quantity sufficient to be analyzed. M. Chevreul found it composed of:

Oxygen, - - - - - - - - - -	11.00
Carbonic acid, - - - - - - - -	14.00
Pure hydrogen, - - - - - - - -	3.55
Azote, - - - - - - - - - - -	71.45
Total, - - - - - -	100.00

There is rarely any gas found in the stomach of a dog. We cannot then believe, with Professor Chaussier, that we swallow a bubble of air at every motion of deglutition, which is pressed into the stomach by the alimentary bolus. Were it so, there ought to be found a considerable quantity of air in this organ after a meal: now the contrary is to be seen.

E. There is never a great quantity of chyme accumulated in the pyloric portion; the most that I have seen in it was scarcely equal in volume to two or three ounces of water. The contraction of the stomach appears to have an influence upon the production of chyme. The following is what I have observed in this respect. After having been some time immoveable, the extremity of the duodenum contracts, the pylorus and the pyloric portion contract also; this motion presses the chyme towards the splenic portion; but it afterwards presses it in a contrary direction, that is, after being distended, and having permitted the chyme to enter again into its cavity, the pyloric portion contracts from left to right, and directs the chyme

Motions of the stomach during the formation of chyme.

towards the duodenum, which immediately passes the pylorus and enters the intestines.

The same phenomenon is repeated a certain number of times, but it stops to begin again, after a certain time. When the stomach contains much food this motion is limited to the parts of the organ nearest the pylorus; but in proportion as it becomes empty the motion extends farther, and is seen even in the splenic portion when the stomach is almost entirely empty. It becomes generally more strong about the end of chymification. Some persons have a distinct feeling of it at this moment.

Uses of the pylorus.

The pylorus has been made to play a very important part in the passage of the chyme from the stomach to the intestine. It judges, they say, of the chymification of the food; it opens to those that have the required qualities, and shuts against those that have not. However, as we daily observe substances not digestible traverse it easily, such as stones of cherries, it is added, that becoming accustomed to a substance not chymified, which presents itself repeatedly, it at last opens a passage. These considerations, consecrated in a certain degree by the word *pylorus, a porter*, may please the fancy, but they are purely hypothetical.

F. All the alimentary substances are not transformed into chyme with the same promptitude.

Experiments upon the formation of chyme.

Generally the fat substances, the tendons, the cartilages, the concrete albumen, the mucilaginous and sweet vegetables, resist more the action of the stomach than the caseous, fibrinous, glutinous substances. Even some substances appear refractory: such as the bones, the epidermis of fruits, their stones, and whole seeds, &c.

In determining the digestibility of food, the volume of the portions swallowed ought to be taken into account. I have often observed that the largest pieces, of whatever nature, remained longest in the stomach; on the contrary, a substance which is not digestible, if it is very small, such as grape stones, does not rest in the stomach, but passes quickly with the chyme into the intestine.

Remarks upon the formation of chyme.

In respect of the facility and quickness of the formation of chyme it is different in every different individual. It is evident, after what has been said, that to fix the necessary time for the chymification of all the food contained in the stomach, we ought to take into account their quantity, their chemical nature, the manner in which the mastication acts upon them, and the individual disposition. However, in four or five hours after an ordinary meal, the transformation of the whole of the food into chyme is generally effected.

The nature of the chemical changes that the food undergoes in the stomach is unknown. It is not because there have been no attempts at different periods to give explanations of them more or less plausible. The ancient philosophers said that the food became putrified in the stomach; Hippocrates attributed the digestive process to coction; Galen assigned to the stomach attractive, retentive, concoctive, expulsive, faculties, and by their help he attempted to explain digestion. The doctrine of Galen reigned in the schools until the middle of the seventeenth century, when it was attacked and overturned by the *fermenting chemists*, who established in the stomach an *effervescence*, a particular fermentation, by means of which the food was *macerated, dissolved, precipitated, &c.*

Systems of digestion.

This system was not long in repute; it was replaced by ideas much less reasonable. Digestion was supposed to be only a trituration, a bruising performed by the stomach; an innumerable quantity of little worms was supposed to attack and divide the food. Boerhaave thought he had found the truth by combining the different opinions that had reigned before him. Haller did not follow the ideas of his master; he considered digestion a simple *maceration*. He knew that vegetable and animal matters plunged into water are soon covered with a soft homogeneous layer; he believed that the food underwent a like change, by macerating in the saliva and fluids secreted by the stomach.

If these different systems are treated with the severe logic which ought henceforward to reign in Physiology, we can see nothing in them but the necessity of our satisfying the imagination, and forming theories, however illusory, of things of which we are ignorant. In fact, was it a great advancement to say that digestion was a coction, a fermentation, a maceration, &c.? No, for there was no precise sense attached to these words.

Experiments of Reaumur and Spallanzani upon the formation of chyme.

Reaumur and Spallanzani did not follow this plan. They made experiments on animals, and demonstrated the falsity of the ancient systems; they showed that food, contained in hollow metallic balls pierced with small holes was digested the same as if it was free in the cavity of the stomach. They proved that the stomach contains a particular fluid, which they call *gastric juice*, and that this fluid was the principal agent of digestion; but they much exaggerated its properties, and they were mistaken when they thought to have explained digestion in considering it as a *solution:* because, in not explaining this solution, they did not explain the changes of food in the stomach.

Instead of stopping to explain or refute these different hypotheses, which are found in all the different works on this subject, we will make the following reflections upon the formation of the chyme: Reflections upon the formation of chyme.

In the formation of chyme, it is necessary to consider, 1st, the circumstances in which the food is found in the stomach; 2dly, the chemical nature of it.

The circumstances affecting the food in the stomach during its stay there are not numerous: 1st, it suffers a pressure more or less strong either from the sides of the abdomen, or from those of the stomach; 2dly, the whole is entirely moved by the motions of respiration; 3dly, it is exposed to a temperature of thirty to thirty-two degrees of Reaumur; 4thly, it is exposed to the action of the saliva, of the mucosities proceeding from the mouth and the œsophagus, as well as the fluid secreted by the mucous membrane of the stomach.

It will be remembered that this fluid is slightly viscous, that it contains much water, mucus, salts, with a base of soda and ammonia, and lactic acid of M. Berzelius.

With regard to the nature of the food, we have already seen how variable it is, since all the immediate principles, animal or vegetable, may be carried into the stomach in different forms and proportions, and serve usefully in the formation of chyme.

Now, making allowance for the nature of the food, and the circumstances in which it is placed in the stomach, shall we be able to account for the known phenomena of the formation of chyme? The temperature of thirty to thirty-two degrees, R=100, to 104 F; the pressure, and the tossing that the food sustains, cannot be considered as the principal cause of its transformation into chyme; it is probable that they only co-operate in this; the action of the saliva and that of the fluid secreted in the stomach remain; but after the known composition of the saliva it is hardly possible that it can attack and change the nature of the food; at most, it can only serve to divide, to imbibe it in such a manner as to separate its particles: It must then be the action of the fluid formed by the internal membrane of the stomach. It appears certain that this fluid, in acting chemically upon the alimentary substances, dissolves them from the surface towards the centre.

Artificial digestion.

To produce a palpable proof of it, with this fluid of which we speak, there have been attempts made to produce what is called in physiology, since Reaumur and Spallanzani, *artificial digestions,* that is, after having macerated food, it is mixed with gastric juice, and then exposed in a tube or any other vessel to a temperature equal to that of the stomach. Spallanzani advanced that these digestions succeeded, and that the food was reduced to chyme; but, according to the researches of M. de Montegre, it appears that they are not; and that, on the contrary, the substances employed undergo no alteration analogous to chymification; this is agreeable to experiments made by Reaumur. But because the gastric juice does not dissolve the food when put with it into a tube, we ought not to conclude like some persons that the same fluid cannot dissolve the food when it is introduced into the stomach; the circumstances are indeed far from being the same: in the stomach, the temperature is constant, the food is pressed and agitated, and the saliva and gastric juice are constantly renewed; as soon as the chyme is formed it is carried away and pressed into the duodenum. Nothing of this takes place in the tube or vase which contains the food mixed with gastric juice; therefore, the want of success in artificial digestions, proves nothing which tends to explain the formation of chyme.

Reflections on the formation of chyme.

But how does it happen that the same fluid can act in a manner similar upon the great variety of alimentary substances, animal and vegetable? The acidity which characterizes it, though fit to dissolve certain matters, as albumen, for example, would not be suitable for dissolving fat.

To this it may be answered, that nothing proves the gastric juice to continue always the same; the small number of analyses that have been made of it demonstrate, on the contrary, that it presents considerable varieties in its properties. The contact of different sorts of food upon the mucous membrane of the stomach may possibly influence its composition ; it is at least certain, that this varies in the different animals. For example, that of man is incapable of acting on bones ; it is well known that the dog digests these substances perfectly.*

Generally speaking, the action by which the chyme is formed prevents the re-action of the constituent elements of the food upon each other : but this effort takes place only in good digestions ; in bad digestion, fermentation, and even putrefaction may take place : this may be suspected by the great quantity of inodorous gases that are developed in certain cases, and the sulphuretted hydrogen which is disengaged in others.

Influence of the nerves of the eighth pair upon the formation of chyme.

The nerves of the eighth pair have long been considered to direct the act of chymification : in fact, if these nerves are cut, or tied in the neck, the matters introduced into the stomach undergo no alteration. But the consequence that is deduced from this fact does not appear to me to be rigorous. Is not the effect produced upon the stomach by the injury done to respiration, confounded here with the direct influence of the section of the nerves of the eighth pair upon this organ ? I am inclined to believe it ; for, as I have many times done, if the two eighth pairs be cut in the breast *below* the branches which go to the lungs, the food which is introduced afterwards into the stomach is transformed into chyme, and ultimately furnishes an abundant chyle.

Some persons imagine that electricity may have an influence in the production of chyme, and that the nerves we mention may be the conductors : there is no established fact to justify this conjecture. The most probable use of the nerves of the eighth pair is, to establish intimate relations between the stomach and the brain, to give notice whether any noxious substances have entered along with the food, and whether they are capable of being digested.

Internal sensations that accompany the formation of chyme.

In a strong person, the operation of the formation of chyme takes place without his knowledge ; it is merely perceived that the sensation of fulness, and the difficulty of respiration produced by the distension of the stomach, disappear by degrees ; but frequently, with people of a

* We must beware, however, of these conjectural varieties of the animal fluids. As analytical chemistry improves, the composition of animal and vegetable matters is found to be much more constant than we were disposed to believe.

delicate temperament, digestion is accompanied with feebleness in the action of the senses, with a general coldness, and slight shiverings; the activity of the mind diminishes, and seems to become drowsy, and there is a disposition to sleep. The vital powers are then said to be concentrated in the organ that acts, and to abandon for an instant the others. To those general effects are joined the production of the gas that escapes by the mouth, a feeling of weight, of heat, of giddiness, and sometimes of burning, followed by an analogous sensation along the œsophagus, &c. These effects are felt particularly towards the end of the chymification.—It does not appear, however, that these laborious digestions are much less beneficial than the others.

Action of the Small Intestine.

Action of the small intestine.

The small intestine is the longest portion of the digestive canal; it establishes a communication between the stomach and the large intestine. Not being susceptible of much distension, it is twisted a great many times upon itself, being much longer than the place in which it is contained. It is fixed to the vertebral column by a fold of the peritoneum, which limits, yet aids its motions; its longitudinal and circular fibres are not separated as in the stomach; its mucous membrane, which presents many *villi*, and a great number of mucous follicles, forms irregular circular folds, the number of which are greater in proportion as the intestine is examined nearer the *pyloric* orifice: These folds are called *valvulae conniventes.*

The small intestine receives many blood vessels; its nerves come from the *ganglions* of the *great sympathetic.* At its internal surface the numerous orifices of the chyliferous vessels open.

This intestine is divided into three parts, called the duodenum, jejunum, and ileum; but this division is of little use in Physiology.

The mucous membrane of the small intestine, like that of the stomach, secretes abundance of mucus: I do not think it has ever been analyzed. It appears to me to be viscous, thready, of a salt taste, and reddens strongly turnsol paper; all which properties we have already remarked in the liquid secreted by the stomach. Haller gave this fluid the name of *intestinal juice;* the quantity that is formed in twenty-four hours he estimated at eight pounds.

We remark, not far from the gastric extremity of this intestine, the common orifice of the biliary and pancreatic canals, by which the fluid secreted by the liver and the pancreas flow into the intestinal cavity. If the formation of the chyme is still a mystery, the nature of the phenomena that take place in the small intestine are little better known. We will follow here our ordinary method; that is, we will describe only what we know from observation.

We will first speak of the entrance of the chyme, and its passage through the small intestine; afterwards we will notice the changes that it suffers.

Accumulation and Passage of the Chyme in the small Intestine.

Accumulation of chyme in the small intestine.

In dogs, I have frequently had occasion to see the chyme pass from the stomach into the duodenum. The phenomena that I have observed are these. At intervals, more or less distant, a contractile motion commences towards the middle of the duodenum; it is propagated rapidly to the site of the pylorus: this ring contracts itself as also the pyloric part of the stomach; by this motion, the matters contained in the duodenum are pressed back towards the pylorus, where they are stopped by the valve, and those that are found in the *pyloric* part, are partly pressed towards the *splenic* part; but this motion, directed from the intestine towards the stomach, is very soon replaced by another in a contrary direction, that is, which propagates itself from the stomach towards the duodenum, the result of which is to make a considerable quantity of chyme pass the pylorus.

Motion of the pylorus.

Passage of chyme through the pylorus.

This fact seems to indicate that the valve of the pylorus serves as much to prevent the matters contained in the small intestine from flowing back into the stomach, as to retain the chyme and the food in the cavity of this organ.

The motion that we have described, is generally repeated many times following, and modified as to the rapidity, the intensity of the contraction, &c.; it then ceases to begin again after some time. It is not very marked in the first moments of the formation of the chyme; the extremity only of the pyloric part participates in it. It augments in proportion as the stomach becomes empty:

and, towards the end of chymification, I have often seen it take place over the whole stomach. I have ascertained that it is not suspended by the section of the nerves of the eighth pair.

Thus the entrance of chyme into the small intestine is not perpetual. According as it is repeated, the chyme accumulates in the first portion of the intestine, it distends its sides a little, and presses into the intervals of the valves; its presence very soon excites the organ to contract, and by this means one part advances into the intestine; the other remains attached to the surface of its membrane, and afterwards takes the same direction. The same phenomenon continues down to the large intestine; but, as the duodenum receives new portions of the chyme, it happens at last that the small intestine is filled in its whole length with this matter. It is observed only to be much less abundant near the *cœcum* than at the pyloric extremity.

Progress of the chyme in the small intestine.

The motion that determines the progress of the chyme through the small intestine, has a great analogy with that of the pylorus: it is irregular, returns at periods which are variable, is sometimes in one direction, sometimes in another, takes place sometimes in many parts at once; it is always slow, more or less; it causes relative changes amongst the intestinal circumvolutions. It is beyond the influence of the will.

We should form a false idea of it were we merely to examine the intestine of an animal recently dead; it has then a much greater activity than during life. Nevertheless, in weak digestions it appears to acquire more than ordinary energy and velocity.

In whatever manner this motion takes place, the chyme appears to move very slowly in the small intestine: the numerous valves that it contains, the multitude of asperities that cover the mucous membrane, the many bendings of the canal, are so many circumstances that ought to contribute to retard its progress, but which ought to favour its mixture with the fluids contained in the intestine, and the production of the chyle which results from it.

Changes that the Chyme undergoes in the small Intestine.

It is only about the height of the orifice of the *choledochus* and pancreatic canal that the chyme begins to change its properties. Before this, it preserves its colour, its semi-fluid consistence, its sharp odour, its slightly acid savour; but, in mixing with the bile and the pancreatic juice. it assumes new qualities: its colour becomes yellowish, its taste bitter, and its sharp odour diminishes much. If it proceeds from animal or vegetable matters, which contained grease or oil, irregular filaments are seen to form here and there upon its surface; they are sometimes flat, at other times rounded, attach themselves quickly to the surface of the valve, and appear to consist of crude chyle. This matter is not seen when the chyme proceeds from matter that contained no fat; it is a greyish layer, more or less thick, which adheres to the mucous membrane, and appears to contain the elements of chyle. The same phenomena are observed in the *two superior thirds* of the small intestine; but in the *inferior third*, the chymous matter is more consistent; its yellow colour becomes more deep; it ends sometimes by becoming of a greenish brown, which pierces through the intestinal parietes, and gives an appearance to the *ileum*, distinct from that of the *duodenum* and *jejunum*. When it is examined near the *cæcum*, there are few or no whitish chylous striae seen; it seems, in this place, to be only the remainder of the matter which has served in the formation of the chyle.

Alteration of the chyme in the small intestine.

After what has been said above, upon the varieties that the chyme presents, we may understand that the changes it undergoes in the small intestine are variable according to its properties; in fact, the phenomena of digestion in the small intestine, vary according to the nature of the food.* The chyme, however, preserves its acid property; and if it contains small quantities of food or other bodies that have resisted the action of the stomach, they traverse the small intestine without undergoing any alteration. The same phenomena appear when the same substances have been used. I have recently been able to ascertain this fact upon the bodies of two criminals who, two hours before death, had taken an ordinary meal, in which they had eaten the same food nearly in equal quantity; the matters contained in the stomach, the chyme in the pyloric portion and in the small intestine, appeared to me exactly the same as to consistence, colour, taste, odour, &c.

* We have made many experiments on this point, but the details would be useless in an elementary work.

Gas contained in the small intestine.

There is generally gas found in the small intestine during the formation of chyle. M. Jurine, of Geneva, was the first who examined it with attention, and pointed out its nature; but at the period when this learned physician wrote, eudiometric processes were very far from their present perfection. I have thought it necessary, therefore, to make new researches upon this interesting point; M. Chevreul has been kind enough to assist me in the execution of this labour. Our experiments were made upon the bodies of criminals opened shortly after death, and who being young and vigorous presented the most favourable conditions for such researches. In a subject of twenty-four years, who had eaten, two hours before his death, bread, and some Swiss cheese, and water reddened with wine, we found in the small intestine:

Oxygen	0.00
Carbonic Acid	24.39
Pure Hydrogen	55.53
Azote	20.08
Total	100.00

In a second subject, aged twenty-three years, who had eaten of the same food at the same hour, and whose punishment took place at the same time:

Oxygen	0.00
Carbonic Acid	40.00
Pure Hydrogen	51.15
Azote	8.85
Total	100.00

In a third experiment, made upon a young man of twenty-eight years, who, four hours before death had eat bread, beef, lentiles, and drank red wine, we found in the same intestine—

Oxygen	0.00
Carbonic Acid	25.00
Pure Hydrogen	8.40
Azote	66.60
Total	100.00

Origin of the gases contained in the small intestine.

We never observed any other gases in the small intestine. These gases might have different origins. They might possibly come from the stomach with the chyme; or they were perhaps, secreted by the intestinal mucous membrane; they might arise from the reciprocal action of the matters contained in the intestine; or perhaps they might come from all these sources at once.

However, the stomach contains oxygen, and very little hydrogen, whilst we have almost always found much hydrogen in the small intestine, and never any oxygen. Besides, it is a daily observation, that the little gas that the stomach contains is generally passed by the mouth towards the end of chymification, probably, because at this instant it can more easily advance into the œsophagus.

The probability of the formation of gases by the secretion of the mucous membrane could not be at all admissible, except for carbonic acid, which seems to be formed in this manner in respiration. With regard to the action of matters contained in the intestine, I have many times seen the chymous matter let bubbles of gas escape very rapidly. This phenomenon took place from the orifice of the ductus choledochus to the commencement of the *ilium*: there was no trace of it perceived in this last intestine, nor in the superior part of the duodenum, nor the stomach. I have made this observation again upon the body of a criminal four hours after death; it presented no traces of putrefaction.

Nature of the changes that the chyme undergoes in the small intestine.

The alteration which chyme undergoes in the small intestine is unknown; it is easily seen to be the result of the action of the bile, of the pancreatic juice, and of the fluid secreted by the mucous membrane, upon the chyme. But what is the play of the affinities in this real chemical operation, and why is the chyle precipitated against the surface of the *valvulae conniventes*, whilst the rest remains in the intestine to be afterwards expelled? This is completely unknown.

We have learned something more of the time that is necessary for this alteration of the chyme. The phenomenon does not take place quickly: in animals, it often happens that we do not find any chyle formed three or four hours after the meal.

After what has been said, we see that in the small intestine, the chyme is divided into two parts: the one which attaches itself to the sides, and which is the chyle still impure; the other the true refuse, which is destined to be thrown into the large intestine, and afterwards entirely carried out of the body.

Thus is accomplished the important phenomenon of digestion, the production of chyle: those that remain to be examined are only the complement of it.

Action of the Large Intestine.

The large intestine has a considerable extent; it forms a large circuit in coming from the right iliac fossa, where it commences, to the anus, where it terminates.

Of the large intestine.

It is divided into *cæcum*, *colon*, and *rectum*. The *cæcum* is situated in the right iliac region; it is placed close to the end of the small intestine. The *colon* is divided into the ascending portion, which extends from the *cæcum* to the right *hypochondrium;* into the transverse portion, which is directed horizontally from the right hypochondrium to the left; and into the descending portion, which is prolonged to the excavation of the pelvis. The rectum is very short; it begins where the *colon* finishes, and terminates in the formation of the anus.

Structure of the large intestine.

In this passage, the large intestine is fixed by folds of the *peritoneum*, so disposed as easily to permit variations of volume. Its muscular layer has a particular disposition. Its longitudinal fibres form three straight bundles, far separated from each other when the intestine is dilated. Its circular fibres form also bundles much more numerous, but equally separated. From this results that, in a great number of points, the intestine is formed only of the peritoneum and the mucous membrane.(67) These places are generally formed into distinct cavities, where the excremental matters are accumulated. The *rectum* does not present this disposition; its muscular layer is very thick, uniformly spread, and appears to possess a more powerful contraction.

The mucous membrane of the large intestine is not covered with *villi* like that of the small intestine and stomach; it is, on the contrary, smooth. Its colour is pale red; there are only a small number of follicles remarked in it. At the junction of the *cæcum* with the small intestine, there exists a valve evidently disposed to permit matters to pass into this intestine, but to prevent their return into the small intestine. Much fewer arteries and veins come to the large than to the small intestine: the same is true of the nerves and lymphatic vessels.

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(67) See Morgagni, Ep. 14, n. 8.

Accumulation and Passage of the Feces in the Large Intestine.

The contraction of the inferior portion of the *ilium* determines the matter that it contains to penetrate into the *cæcum*. This motion, which is irregular, returns at distant intervals: it is rarely seen in living animals, but it is frequently perceived in animals that have just been killed. It has no coincidence with that which the pylorus presents. Accumulation of excrement in the large intestine.

In proportion as this motion is repeated, the matter that comes from the *ilium* accumulates in the *cæcum:* it cannot return into the small intestine, for the *ilio-cæcal* valve prevents it; it has no issue but by the opening that communicates with the *colon*. Once introduced into the *cæcum* it takes the name of *excremental, fecal, stercoral, matter*, &c.

After having remained a certain time in the *cæcum*, the excremental matters pass into the *colon*, the different portions of which it passes through in succession; sometimes forming a continued mass, sometimes isolated masses, which fill one or many of the compartments that the intestine presents in its whole length. This progression, which is generally very slow, takes place by the influence of the contraction of the muscular fibres, and of the pressure that the intestine supports in an organ contained in the abdomen: it is procured by the follicular and mucous secretion of the internal membrane.

Being arrived at the rectum, the matter accumulates, distends its parietes uniformly, and forms a mass sometimes of several pounds. It cannot proceed further, for the anus is always shut by the contraction of the two *sphincter* muscles.

The consistence of the *feces* in the large intestine is very variable; however, in a man in good health, it is more considerable than that which passes from the small intestine. Its solidity generally increases as it approaches the *rectum*; but it there becomes soft by absorbing the fluids secreted by the mucous membrane.

Changes of the Feces in the Large Intestine.

The feces have not the fetid odour proper to human excrements before their passage into the large intestine; Changes that the feces undergo in the large intestine.

they contract their odour even by remaining there for the shortest time.

Their yellowish brown colour becomes more deep; but with regard to the consistence, odour, colour, &c., there are numerous varieties that depend on the nature of the food digested, or the manner in which chymification and chylification have taken place; and on the habitual disposition, or that which existed during the operation of former digestions.

Amongst the feces are found all the matters that have not been changed by the action of the stomach: there are also often seen stones of fruit, grains, and other vegetable substances.

Several celebrated chemists have been engaged in the analysis of human excrement; M. Berzelius found them composed of—

Water,	73.3
Vegetable and animal remains,	7.0
Bile,	0.9
Albumen,	0.9
Peculiar extractive matter,	2.7
Matter formed of the altered bile, of resin, animal matter, &c.,	14.0
Salts,	1.2
Total,	100.0

These analyses made with the intention of explaining the mystery of digestion, can afford us in the mean time very small assistance: for in order that they should present this advantage, it would be necessary to vary them very much, to take into account the nature and quality of the aliments formerly used, to consider the individual disposition, to act at first only on excrements proceeding from very simple alimentary substances; but such a labour supposes a perfection in the means of analysis to which animal chemistry is not yet perhaps arrived.

Gas contained in the large intestine.

There exist also gases in the large intestine when it contains excremental matters. M. Jurine long since determined their nature, but he has made only one satisfactory experiment on this subject. In the large intestine of an insane person, found in the morning dead of cold in his cell, and immediately opened, he found azote, carbonic acid, carburetted hydrogen and sulphuretted hydrogen.

M. Chevreul and I examined with care the gases that were found in the large intestine of the criminals of whom I spoke at the article *small intestine.* In the subject of the first mentioned experiment, the large intestine contained in a hundred parts of gas:—

COLON.

Oxygen, - - - - - - - - - -	0.00	
Carbonic Acid, - - - - - - - -	43.50	
Carburetted hydrogen, and traces of sulphuretted hydrogen, - - -	5.47	
Azote, - - - - - - - - - -	51.03	
		100.00

The subject of the second experiment presented in the same intestine:—

Oxygen, - - - - - - - - - -	0.00	
Carbonic acid, - - - - - - - -	70.00	
Pure hydrogen, and carburetted hydrogen, - - - - - - - - -	11.06	
Azote, - - - - - - - - - - -	18.04	
		99.10

Upon the subject of the third experiment we separately analyzed the gas found in the *cœcum* and that found in the *rectum.* The result was:—

CÆCUM.

Oxygen, - - - - - - - - - -	0.00	
Carbonic acid, - - - - - - - -	12.50	
Pure hydrogen, - - - - - - - -	7.50	
Carburetted hydrogen, - - - -	12.50	
Azote, - - - - - - - - - - -	67.50	
		100.00

RECTUM.

Oxygen, - - - - - - - - - -	0.00
Carbonic acid, - - - - - - - -	42.86
Carburetted hydrogen, - - - -	11.18
Azote, - - - - - - - - - - -	45.96
Total, - - - - -	100.00

Some traces of sulphuretted hydrogen were shown upon mercury before the gas was analyzed.

These results, which may be confided in, since all means were used to prevent errors, agree pretty well with those that M. Jurine obtained long since relatively to the nature of the gases; but they weaken what he said with regard to the carbonic acid, the quantity of which, according to that physician, becomes less and less from the stomach to the rectum. On the contrary, we have seen that the proportion of this acid increases more as the distance is greater from the stomach.

Origin of the gases in the large intestine.

The same doubts that we expressed as to the origin of the gases contained in the small intestine exist for those of the large intestine. Do they come from the small intestine? Are they secreted by the mucous membrane? Are they formed at the expense, and by the re-action of the constituent principles of the fecal matters? Or do they proceed from this triple source? It is not easy to remove our uncertainty in this respect.

We may notice, however, that these gases differ from those of the small intestine. In the last, pure hydrogen predominates often, whilst there is none found in the large intestine, but only carburetted and sulphuretted hydrogen. Besides, I have frequently seen abundance of gases arising from the matter of the large intestine under the form of an innumerable multitude of small bubbles.

After what we have seen we may conclude that the large intestine is of little importance in the production of chyle. That organ fulfils very well the functions of a receptacle, in which is deposited for a certain time the residue of the chemical digestive operation in order to be afterwards expelled. We may even conceive that digestion could be completely effected without the aid of the large intestine. Nature presents this circumstance in individuals with an artificial anus, in which the *cœcal* extremity of the small intestine ends, and by which the matters escape that have served in the formation of the chyme.

Expulsion of the Feces.

The principal agents in the excretion of the feces are the diaphragm and abdominal muscles; the colon and the rectum co-operate in it, but with little efficacy.

Feeling that announces the necessity of expelling the feces.

As long as the excremental matters are not in great quantity in the large intestine, and particularly so long as they are not accumulated in the rectum, we are not sensible of their presence; but when their quantity is considerable, and they distend the rectum, then there is a sensation of fulness and uneasiness in the abdomen.

This feeling is soon replaced by another much more vivid, which informs us of the necessity of relieving ourselves. If this feeling is not attended to, on certain occasions it ceases and commences again after a time of more or less continuation: at other times it increases quickly, and with such force that in spite of every effort to the contrary, the excrements would pass out, were the impulse not attended to.

The vehemence of this necessity is modified by the consistence of the excremental matter. It is almost impossible to resist beyond a few instants the expulsion of soft and almost liquid matters, whilst it is easy to retard that of other matters that have more solidity.

Nothing is more easy to understand than the mechanism of the expulsion of the excrements: in order that this may take place, the matters accumulated in the rectum must be pressed with a force superior to the resistance of the muscles of the anus. The contraction of the rectum alone could not produce such an effect, notwithstanding the considerable thickness of its muscular layer; other powers must aid in it. Mechanism of the expulsion of the feces.

These are, on the one hand, the diaphragm, which presses directly downwards the whole mass of the viscera; on the other, the abdominal muscles, which contract and press them against the vertebral column. From the combination of these two forces results a considerable pressure, which bears upon the fecal matter gathered in the rectum; this being too great for the resistance of the sphincters, they give way, the matter enters the anus, and soon passes out.

But as the cavity of the rectum is much larger than the opening of the anus, which contracts constantly, in order to pass out, the matter must be formed according to the diameter of this opening: it passes so much more easily as its consistence is less; when it is more solid, it is also necessary to employ more force. If it is liquid, the contraction of the rectum alone seems sufficient for its expulsion. Expulsion of the excrements.

A phenomenon analogous to that which happens to the œsophagus, when the food enters the stomach, has been observed in the rectum by M. Hallé. This learned Professor remarked that, in the efforts to go to the water-closet, the internal membrane of the intestine is displaced, and pressed down, and forms a projection near the anus. This effect must be produced, in a great measure, by the contraction of the circular fibres of the rectum.

Periods of expulsion of the feces.

The necessity of rendering the fecal matters is renewed at periods that are variable, according to the quantity and nature of the food used, and the individual disposition. Generally it is not shown until after several meals. With some persons evacuation takes place once or twice in twenty-four hours; but there are others who are ten or twelve days without having any, and who nevertheless enjoy perfect health.

Habit is one of the causes that have most influence upon the regular return of the excretion of the feces: when it is once contracted, we may go to the water-closet exactly at the same hour. Many persons, particularly females, are obliged to have recourse to particular means, such as clysters, in order to get rid of the matters accumulated in the large intestine.

Expulsion of gas from the large intestine.

The gases are not subjected to this periodic and generally regular expulsion; their motion is more rapid. Their displacement being easy they very soon arrive at the anus, merely by the effect of the peristaltic motion of the large intestine; however, the contraction of the sides of the abdomen is necessary to be added to determine the passage outward, which take place with noise: this rarely happens when they are expelled by the contraction of the rectum alone.

In other respects, the passage of the gases from the anus is neither regular nor constant. Many people seldom or never pass any; others do so continually. The use of certain foods has a considerable influence upon their formation and expulsion. Their development is generally considered as an indication of bad digestion. In health, as in sickness, the repeated passage of air by the anus announces the necessity of returning to the water-closet.

By the expulsion of the feces is completed this complicated function, the essential end of which is the formation of the chyle; but we should have a very imperfect idea of it, if, like many esteemed authors, we treated only of the digestion of the food. Another kind of consideration presents itself for our study: this is the digestion of liquid aliments, or drinks.

Of the Digestion of Drinks.

Digestion of drinks.

It is very singular that physiologists, who have been so much engaged with the digestion of solid foods, and who have erected so many systems to explain it, and made so many experiments to throw light upon its nature, have never paid any particular attention to that of drinks; this study, however, presented fewer apparent difficulties than the former. Drinks are generally less compounded than the foods, though there are several of them very nourishing; the greater part are easily digested. This single circumstance of the digestion of liquids ought to have caused the rejection of the systems of trituration, maceration, &c. In fact there is nothing in the drinks which requires bruising, and they nevertheless satisfy hunger, restore the powers, and nourish.

Of the Taking of Drinks.

The taking of drinks may be performed in a multitude of different ways; but *Petit* has shown that they may be reduced to two.* Taking of drinks.

According to the first, the liquid is poured into the mouth; it enters by the effects of its own gravity. We ought to notice the ordinary manner of drinking, in which the lips being in contact with the edge of the vessel, the liquid is poured more or less slowly; the action of gulping down, which consists in projecting into the mouth at once all that the vessel contains; and the action of drinking *à la regalade*, in which the head being turned backward, and the jaws separated, the liquid is let fall from a certain height, in a continued jet, into the mouth.

According to the second mode of taking drinks, the air is drawn from the mouth, and the pressure of the atmosphere forces the liquid to enter: such are the actions of *aspiration*, *sipping*, *sucking*, or *drawing*, &c.

When we aspire, the mouth is applied to the surface of a liquid; the breast is then dilated, so as to diminish the pressure of the atmosphere upon the portion of the liquid intercepted by the lips. The liquid immediately enters to supply the place of the air subtracted from the mouth. Sucking by aspiration.

In the action of sucking at the breast, the mouth represents very well a sucking pump, the opening of which is formed by the lips, the body by the cheeks, the palate, &c.; and the piston by the tongue. Action of sucking at the breast.

When this is put in operation, the lips are applied exactly round the body from which the liquid is to be extracted; the tongue adapts itself; it soon contracts, di-

* Mem. de l'Acad. des Scien. 1715—1716.

minishes in volume, is drawn backward, and there is a vacuum partly produced between its superior surface and the palate: the liquid, contained in the body that is sucked, not being equally compressed by the atmosphere, is displaced, and the mouth is filled.

Drinks do not remain in the mouth, having no need of mastication or insalivation; they are swallowed as soon as they enter. They scarcely undergo any changes in passing this cavity except in their temperature. If, however, its taste is strong or disagreeable, or from finding it pleasant we continue it, it happens, that the presence of drink in the mouth causes a greater or less quantity of saliva and mucus to flow, which mixes with the drink.

Deglutition of Drinks.

Deglutition of drinks.

We swallow liquids by the same mechanism as solid foods; but as drinks slide more easily upon the surface of the mucous membrane of the palate, tongue, and pharynx; as they cede without difficulty to the least pressure, and always present the qualities required for traversing the pharynx, they are generally swallowed with less difficulty than the solid foods.

I do not know why the contrary opinion generally exists. They affirm that the atoms of liquids have a continual tendency to separate, and therefore ought to present a greater resistance to the action of the organs of deglutition; but daily experience contradicts this assertion.

Every one may easily determine by his own experience that it is more easy to swallow liquids than solids, even when they are sufficiently attenuated and impregnated with saliva.*

We call a *gulp* the quantity of liquid swallowed at each motion of deglutition. The volume of *gulps* is variable; but however voluminous they are, as they suit the form of the pharynx and the œsophagus, they never produce any painful distension in these canals, such as is seen in the case of solid food.

In the ordinary manner of drinking, the deglutition of liquids presents the three periods that we have already described; but when we gulp, or drink *à la régalade*, the

* Deglutition, as performed in disease, affords no exception: if the throat be at all inflamed, the sick can swallow nothing whatever except liquids.

liquid being directly carried into the pharynx, only the two last periods take place.

Accumulation and duration of Drinks in the Stomach.

The manner in which drinks accumulate in the stomach differs little from that of the aliments; it is generally quicker, more equal, and more easy; probably because the liquids spread, and distend the stomach more uniformly. In the same manner as the food, they occupy more particularly its left and middle portion; the pyloric, or right extremity contains always much less. Accumulation of drinks in the stomach.

The distension of the stomach must not, however, be carried to a great degree, for the liquid would be expelled by vomiting. This frequently happens to persons that swallow a great quantity of drink quickly. When we wish to excite vomiting in persons who have taken an emetic, one of the best means is to make them drink a number of glasses of liquid quickly.

The presence of drinks in the stomach produces local phenomena like those that we have described at the article on the *accumulation of the aliments;* the same changes in the form and position of the organ, the same distension of the abdomen, the same contraction of the pylorus and the œsophagus, &c.

The general phenomena are different from those produced by the aliments: this depends on the action of the liquids upon the sides of the stomach, and the quickness with which they are carried into the blood.

Potations, in passing rapidly through the mouth and the œsophagus, preserve more than the food their proper temperature until they arrive in the stomach. We therefore prefer them to those, when we wish to experience in this organ a feeling of heat or of cold: hence arises the preference that we give to hot drinks in winter, and cold drinks in summer.

Every one knows that the drinks remain much shorter time in the stomach than the aliments; but the manner of their passage out of this viscus is still very little known. It is generally supposed that they traverse the pylorus and pass into the small intestine, where they are absorbed with the chyle; nevertheless a ligature applied round the pylorus in such a manner as to hinder it from penetrating into the duodenum, does not much retard its dis- Stay of drinks in the stomach.

appearance from the cavity of the stomach. We will return to this important point in speaking of the agents of the absorption of drink.

Alteration of Drinks in the Stomach.

Alteration of fluids in the stomach.

Fluids, in respect of the alterations that they prove in the stomach, may be divided into two classes: the one sort do not form any chyme, and the other are chymified wholly or in part.

Drinks that do not form chyme.

To the first class belong pure water, alcohol, sufficiently weak to be considered as a drink, the vegetable acids, &c. During its stay in the stomach, water assumes an equilibrium of temperature with the sides of this viscus: it mixes at the same time with the mucus, the gastric juice, and the saliva which are found in it; it becomes muddy, and afterwards disappears slowly without suffering any other transformation. One part passes into the small intestine; the other appears to be directly absorbed. There remains after its disappearance a certain quantity of mucus, which is very soon reduced to chyme like the aliments. By observation we know that water deprived of atmospheric air, as distilled water, or water charged with a great quantity of salts, as well-water, remain long in the stomach and produce a feeling of weight.

Alcohol acts quite in a different manner. We know the impression of burning heat that it causes at first in its passage through the mouth, the pharynx, the œsophagus; and that which it excites when it enters the stomach: the effects of this action determine the contraction of this organ, irritate the mucous membrane, and augment the secretion of which it is the seat; it coagulates at the same time all the albuminous parts with which it is in contact; and as the different liquids in the stomach contain a considerable proportion of this matter, it happens that a short time after alcohol has been swallowed, there is in this viscus a certain quantity of concrete albumen. The mucus undergoes a modification analogous to that of the albumen; it becomes hard, forms irregular elastic filaments, which preserve a certain transparency.

In producing these phenomena, the alcohol mixes with the water that the saliva and the gastric juice contain; probably it dissolves a part of the elements that enter into their composition, so that it ought to be much weakened by its stay in the stomach. (68) It disappears very quickly; its general effects are also very rapid, and drunkenness or death follow almost immediately the introduction of too great a quantity of alcohol into the stomach.

The matters coagulated by the action of the alcohol are, after its disappearance, digested like solid aliments.

Amongst the drinks that are reduced to chyme, some are reduced in part and some wholly. Drinks reduced to chyme.

Oil is in this last case; it is transformed, in the pyloric part, into a matter analogous in appearance with that which is drawn from the purification of oils by sulphuric acid; this matter is evidently the chyme of oil. On account of this transformation, oil is perhaps the liquid that remains longest in the stomach.

Every one knows that milk curdles soon after it is swallowed; this curd then becomes a solid aliment, which is digested in the ordinary manner. Whey only can be considered as drink.

The greatest number of drinks that we use are formed of water, or of alcohol, in which are in suspension or dissolution, immediate animal or vegetable principles, such as gelatine, albumen, osmazome, sugar, gum, fecula, colouring or astringent matters, &c. These drinks contain salts of lime, of soda, of potass, &c.

The result of several experiments that I have made upon animals, and some observations that I have made on man, is, that there is a separation of the water and the alcohol in the stomach from the matters that these liquids hold in suspension or solution. These matters remain in the stomach, where they are transformed into chyme, like the aliments; whilst the liquids with which they were united are absorbed, or pass into the small intestine; lastly, they are conducted, as we have just now seen, in treating of water and alcohol. Drinks that form chyme.

Salts that are in solution in water do not abandon this liquid, and are absorbed with it.

Red wine, for example, becomes muddy at first by its

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(68) It is nothing more than conjecture, to suppose that alcohol must be weakened by mixture with the elements of the saliva and gastric juice. Many substances, as the volatile oils, increase, when combined with alcohol, its inebriating qualities. Nevertheless, crass mucous, or albuminous matters, seem, in general, to obtund its powers when mixed with it. This is true of milk, sugar, eggs, isinglass, or gelatine.

Experiments upon the formation of the chyme drinks.

mixture with juices that are formed in, or carried into the stomach; it very soon coagulates the albumen of these fluids, and becomes flaky; afterwards, its colouring matter, carried, perhaps, by the mucus and the albumen, is deposited upon the mucous membrane: there is a certain quantity of it seen at least in the pyloric portion; the watery and alcoholic parts disappear with rapidity.

The broth of meat undergoes the same changes. The water that it contains is absorbed; the gelatine, the albumen, the fat, and probably the osmazome, remain in the stomach, where they are reduced into chyme.

Action of the Small Intestine upon Drinks.

Action of the small intestine upon drinks.

After what has been read, it is clear that fluids penetrate, under two forms, into the small intestine: 1st, under that of liquid; 2dly, under that of chyme.

The liquids that pass from the stomach into the intestine remain but a short time, except under particular circumstances; they do not appear to undergo any other alteration than their mixture with the intestinal juice, the chyme, the pancreatic liquid, and the bile; they do not form any sort of chyle; they are generally absorbed in the duodenuum, and the commencement of the jejunum; they are rarely seen in the ilium, and still more rarely in the large intestine. It appears that this last case does not happen except in the state of sickness; for example, during the action of a purgative.

The chyme that proceeds from drinks follows the same rule, and appears to undergo the same changes as that of the food; it therefore produces chyle.

Such are the principal phenomena of the digestion of drinks: we see how necessary it was to distinguish them from those that belong to the digestion of the aliments.

But we do not always digest the aliments and the drinks separately, as we have supposed; very frequently the two digestions take place at the same time.

Simultaneous digestion of the food and the drinks.

Drink favours the digestion of the aliments; this effect is probably produced in various manners. Those that are watery, soften, divide, dissolve even certain foods; they aid in this manner their chymification and their passage through the pylorus.

Wine fulfils analogous uses, but only for the substances that it is capable of dissolving; besides, it excites by its contact the mucous membrane of the stomach, and causes a greater secretion of the gastric juice. Alcohol acts much in the same manner as wine, only it is more intense. It is thus that those liquors which are used after meals, are useful in exciting the action of the stomach.

Remarks upon the Deglutition of Atmospheric Air.

Besides the faculty of swallowing food and drink, many persons can, by deglutition, introduce air enough into their stomach to distend it.

This faculty was long believed to be very rare, and M. Gosse, of Geneva, was quoted as presenting it in a remarkable degree; but I have shown, in a special treatise,* that it is much more common than was generally believed. Of a hundred students in medicine, I have found eight or ten that possessed it.

Persons who easily swallow air

I have shown, in the same work, that the persons who swallow air may be divided into two classes: with the one sort it is an act that is very easy; the other sort do not succeed but with efforts more or less considerable. When these last wish to operate, they must drive all the air out of their chest; after which, filling the mouth with air, so that the cheeks may be a little distended, they perform deglutition in making the chin approach the breast, and removing it again quickly. This deglutition may be compared to that of persons whose throat is inflamed, and who swallow liquids with difficulty and pain.

Persons who swallow air with difficulty.

Persons who cannot swallow air.

With regard to persons who cannot swallow air, and they are the greatest number, I can say, because I have observed it on myself, and on a considerable number of young students, that, with a little practice, one may succeed without much pain. For my part, I succeeded after attempting it two or three days. It is probable that if the deglutition of air were found useful in medicine, the exe-

* Memoir on the Deglutition of Air, read before the Institute, 1815. (69)

(69) Our author's memoir on this subject, contains some curious facts. He concludes it by remarking, that,

"1. Animals swallow air, when they labour under nausea and vomiting.

"2. Pigeons fill their gizzard with air by deglutition, not by inspiration.

"3. It is not rare to meet with persons who swallow air.

"4. In many diseases, particularly in nervous affections, patients sometimes swallow air."

cution of it would not be very long nor difficult for the sick to acquire.

Changes that the air undergoes in the stomach.

In the stomach, the air becomes heated, rarified, and distends that organ. It excites, in some persons, a feeling of burning heat; in others, it produces an inclination to vomit, or very severe pains. Its chemical composition probably changes, but nothing certain is known on this point.

Manner in which the air passes out of the stomach.

Its stay is of more or less continuation; it generally rises again by the œsophagus, and passes out by the mouth or nose; at other times, it traverses the pylorus, spreads through the whole extent of the intestinal canal, and escapes by the anus. In this last case, it distends the whole abdominal cavity, and resembles the disease called *tympanites.*

I have observed that, in certain morbid affections, the sick swallow involuntarily considerable quantities of atmospheric air without perceiving it.

A friend of mine, a young physician, whose digestion is generally difficult, renders it less painful by swallowing, at several times, two or three gulps of air.

Remarks upon Eructation, Regurgitation, Vomiting, &c.

We have seen how the contraction of the œsophagus prevents the matters contained in the stomach, and pressed by the sides of the abdomen, from returning again through that canal: This return takes place sometimes, in consequence of gases or aliments making their way into the œsophagus, and of the sides of the abdomen participating more or less in the action. This sort of reflux is designated by the words, *eructation, belching, regurgitation, vomiting, &c.*

The return of substances that the stomach contains does not take place with equal facility. The gases quit it with more facility than the liquids, and these more easily than solid food. Generally the more the stomach is distended, the more easy is this *anti-deglutition.*

Eructation.

When this viscus contains gases, they necessarily occupy the upper part of it; they are consequently always close to the cardiac opening of the œsophagus. Little as this opening is relaxed, they penetrate into it; and as they are more or less compressed in the stomach, if they are not repelled by the contraction of the œsophagus, they very soon arrive in the upper part, and escape into the pharynx, causing a vibration of the sides of the opening of that cavity: this is called *eructation*. Probably the œsophagus, by a motion opposite to that which it performs in deglutition, becomes partly the cause of the passage out of the gases by the pharynx.

When the gas that passes from the stomach is accompanied by a certain quantity of vapour, or liquid, the eructation takes the name of *belching*.

Voluntary eructation.

In order that eructation take place, it is not necessary that the gases come directly from the stomach; persons who possess the faculty of swallowing air, after having made it pass the pharynx, can let it ascend again into that cavity. By this means voluntary eructation may take place; in ordinary cases it is not subject to the will.

Of involuntary regurgitation.

If, in place of gases, small quantities of solid aliments, or liquids rise from the stomach into the mouth, this phenomenon is called *regurgitation*. It often happens with children, whose stomachs are habitually distended with great quantities of milk; with those who have swallowed an abundance of food or drink, particularly if the stomach is strongly compressed by the contraction of the abdominal muscles: for example, if strong efforts are made to go to stool.

Regurgitation when the stomach is too full.

Regurgitation when the stomach is nearly empty.

Though the distension of the stomach may be favourable to regurgitation, it happens also when the stomach is wholly or nearly empty: thus it is not rare to meet with individuals who, in the morning, throw up a gulp or two of gastric juice mixed with bile. This phenomenon is often preceded by eructations occasioned by the gases that the stomach contained.

When this viscus is very full, it is not probable that its contraction has any effect on the passage of the matters into the œsophagus; the pressure exerted by the sides of the abdomen must be the principal cause of it.

But when the stomach is nearly empty, the motion of the pylorus probably occasions the fluids to enter the œsophagus. This is so much the more probable, as the liquids then thrown up are always more or less mixed with bile, that cannot easily arrive in the stomach without a contractile motion of the duodenum, and the pyloric portion of the stomach. It is understood that the œsophagus contracts with more energy when the stomach is empty.

Voluntary regurgitation.

Regurgitation is involuntary in most individuals, and takes place only in particular circumstances; but there are persons who can produce it when they choose, and who, by this means, get rid of the solid or liquid matters contained in the stomach. Observing them at the instant in which they execute this regurgitation, we see that they first, by an inspiration, lower the diaphragm; they afterwards contract the abdominal muscles so as to compress the stomach; they sometimes aid their action by pressing the epigastric region forcibly with their hands; they remain immoveable an instant, and all at once the liquid, or aliment, enters the mouth. We may presume that the time in which they remain motionless, expecting the appearance of the matters in the mouth, is partly employed in determining the relaxation of the œsophagus, in order that the matters contained in the stomach may be introduced into it. If, in this case, the contraction of the stomach contributes to produce the expulsion of the matter, it is probably but in a very accessary manner.

This voluntary regurgitation is the phenomenon presented by those persons who are believed to *vomit at will.*

There are certain persons who, after a meal, take pleasure in bringing up their food into the mouth, chewing it a second time, and then swallowing it afterwards: in a word, they present a real *rumination,* like certain herbivorous animals.

Of vomiting.

Vomiting is no doubt nearly allied to the phenomenon that we have examined, because the effect of it is to expel, by the mouth, matters contained in the stomach; but it differs from it in many important respects; amongst others, in that particular feeling that announces it, the efforts by which it is accompanied, and the fatigue by which it is always followed.

Of nausea.

That internal sensation which announces the necessity of vomiting is called *nausea;* it consists of a general uneasiness, with a feeling of dizziness in the head, or in the epigastric region: the lower lip trembles, and the saliva flows in abundance. Instantly, and involuntarily, convulsive contractions of the abdominal muscles, and at the same time, of the diaphragm, succeed to this state; the first are not very intense, but those that follow are more so; they at last become such, that the matters contained in the stomach surmount the resistance of the *cardia,* and are thus darted, as it were, into the œsophagus and mouth;

Phenomena of vomiting.

the same effect is produced many times in succession; it ceases for a time, and begins again after some interval. In animals, I have observed that they swallow, in the efforts of vomiting, considerable quantities of air: this air appears intended to favour the pressure exerted by the abdominal muscles upon the stomach. The same phenomenon probably takes place in man.

At the instant that the matters driven from the stomach traverse the pharynx and the mouth, the glottis shuts, the *velum* of the palate rises, and becomes horizontal, as in deglutition; nevertheless, every time that one vomits, a certain quantity of liquid is introduced either into the larynx, or the nasal canals.

Influence of the abdominal muscles upon vomiting.

Vomiting was long believed to depend upon the rapid convulsive contraction of the stomach; but I have shown, by a series of experiments, that, in the process, this viscus is nearly passive; and that the true agents of vomiting are, on the one hand, the diaphragm, and, on the other, the large abdominal muscles; I have even succeeded in producing it, by substituting, for the stomach, in a dog, the bladder of a pig, that I afterwards filled with a coloured liquid.*

In the ordinary state, the diaphragm and the muscles of the abdomen co-operate in vomiting; but each of them can, nevertheless, produce it separately. Thus, an animal still vomits, though the diaphragm has been rendered immoveable by cutting the diaphragmatic nerves; it vomits the same, though the whole abdominal muscles have been taken away by the knife, with the precaution of leaving the linea Alba and the peritoneum untouched.

* See these details, and the Report of the Commissaries of the Institute, in my Memoir on Vomiting, 1813. (70)

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(70) This work of our author's met with great applause at the Institute. The commission, after stating that his Memoir upon vomiting is destined to be for ever quoted in works of Physiology, and worthy, before all, of a distinguished mention in the history of the labours of the class, and an honourable place in its memoirs, concludes by inviting him to extend his experiments. It is not from Cuvier or Pinel, Humboldt or Percy, that science has to fear such puling sentimental horror of vivisection, as has disgraced the medical criticism of this Island for the last seven years. The practice of physic or surgery may, perhaps, be studied on the patient at his own hazard, by practitioners who read nothing but the numbers of their own fees; but anatomy and physiology can only be drawn from the great book of Nature, by close repeated inspection.

I never have seen the stomach contract in the instant of vomiting; we may conceive, however, that the motion of the pylorus may probably take place at this instant. This circumstance presented itself twice to Haller; and made that illustrious physiologist conclude that the contraction of the stomach was the essential cause of vomiting.

Modifications of Digestion by Age.

Digestive organs in the fœtus and the child.

Most authors represent the digestive organs as inactive in the fœtus, and as having, at the period of birth, a development proportional, considerable, necessary, they say, in order to furnish the necessary materials to the nutrition and growth of the body.

If we understand by *inactive*, that the digestive organs of the fœtus do not act upon aliments, no doubt this is true; but if, by this word *absolute inaction* is understood, I think it is wrong; for, it is very probable, that, even in the fœtus, there passes in the digestive organs something very like digestion. We shall have occasion to prove this in the history of the functions of the fœtus.

The same obtains with regard to the development of the digestive system at the period of birth.

Digestive organs of the new-born child.

If we understand only the organs contained in the abdomen, they are indeed proportionally more voluminous than at a more advanced age: but if we mean collectively the whole digestive apparatus, the assertion will be erroneous; for the organs of the prehension and mastication of food, and those of the excretion of the feces, are at the period of birth, and even long after, far from the development that they acquire with the progress of age. Let us not suppose that the energy of the abdominal organs makes up for the weakness of those just mentioned: very far from that, a very delicate and select food, of easy digestion, is necessary for the infant after birth: that which suits it above all others is the milk of its mother; when it is deprived of this, we know with what difficulty a proper substitute can be found for it. In place of considering, then, the digestive organs of a new-born child, or even of one very young, as being endowed with a surplus of force, they ought to be considered as much weaker than they are afterwards.

If, comparatively speaking, the digestive apparatus of the child is not so well disposed as that of the adult, it is perfectly well combined for the sort of action it has to fulfil.

Suction is the mode of prehension proper to children; the parts by which it is performed have a considerable development. The tongue is very large compared to the size of the body. The want of teeth gives a facility to the prolongation of the lips forwards, and to embrace the nipple from which the milk is extracted more exactly than could be done by those of the adult.

Digestive organs in the child.

During the first year, the child has no masticating organs. The jaws are very small and unprovided with teeth; the lower one is not curved, and presents no angle like that of the adult; the elevating muscles, the principal agents of mastication, are very obliquely inserted. A hard cushion, formed by the tissue of the gums, is in lieu of teeth.

Irruption of the teeth.

About the end of the first year, and during the second, the first, or *milk teeth*, arise and furnish the jaws. Their appearance takes place regularly in pairs; at first, the two middle inferior incisors make their appearance, then the superior, afterwards the lateral inferior incisors, very soon afterwards the superior; and in the same successive order, the eye teeth and the small grinders; frequently the latter come first. These last frequently do not come out until the third year. At the age of four years, four new teeth are seen: these are the first large grinders; they complete the number of twenty-four teeth, which the child preserves to seven years. The irruption of the second teething then takes place. The milk teeth generally fall out in the same order in which they appeared in the jaws; they are successively replaced by the teeth that are intended to remain during life. At this period four more large grinders come out. When these have appeared there are altogether twenty-eight teeth. Lastly, about twenty or twenty-five years, sometimes later, the last four grinders or *wisdom teeth* come out, and then the number, which is thirty-two, is complete.

Second teething.

This renewal of the teeth at seven years is rendered necessary by the increase of the jaw. The milk teeth become proportionally too small; those that follow are larger and more solid. Their roots are longer and more numerous; they are firmer in the sockets: these are conditions very favourable to the fulfilment of their functions.

Changes of the inferior jaw.

The jaws change their form while they augment in size; the inferior one becomes bent, its branches become vertical, its body takes a horizontal direction, and the angle that unites them becomes marked.

Changes of the teeth by age.

The teeth are quite new instruments at the time they spring from the maxillary bones. The incisors have a cutting edge, the eye teeth a sharp point, the grinders present conical asperities; but these advantageous dispositions diminish with age. The teeth always rubbing on each other in the motions of mastication, or being in contact with hard bodies, they wear and lose their form by degrees. We may then judge of the age of a man by his teeth, which can be done to a certain degree; but the teeth have so rarely a perfectly regular structure, and an equal degree of hardness, that we can arrive only at an approximation by this means. The wearing of the teeth is generally shown first in the inferior incisors: it is afterwards shown in the grinders, and it makes its appearance much later in the teeth of the upper jaw.

But the wearing of the teeth is not the most unfavourable change produced by age; in the earliest part of confirmed old age they are thrust out of their sockets by the progress of the ossification of the jaws; they become loose and afterwards fall out. The manner in which this takes place is not at all regular like the growth of the teeth; in this respect there are many individual differences.

Organs of mastication in the aged.

Those who do not lose their teeth at the period I have mentioned, ought to consider themselves favoured, for the teeth frequently come out much sooner, sometimes, at other times by blows or falls that tear them out, sometimes by the contact of the air, or of substances that are habitually introduced into the mouth: their tissue then changes, they present spots, become soft, change colour, and at last fall to pieces. These chemical changes are very improperly called *diseases of the teeth*, because they happen also to artificial teeth. After the teeth are all out, the gums harden, the openings that they presented close, the sides of the socket become thin and cutting, and this new form partly supplies the want of the teeth.

Such are the modifications produced by the progress of age upon the organs of mastication; those that happen to the other digestive organs are not sufficiently important to be mentioned.

We will finish this article in remarking that many voluntary muscles contribute to digestion, and undergo by age the same changes that we have mentioned in treating of the modifications that the organs of muscular contraction experience from this cause.

Our knowledge is very limited with regard to the modifications that digestion suffers in different ages: what we know of it relates more especially to the manner of taking in the food, its mastication, and the excretion of the fecal matters: probably the changes that the abdominal digestive organs undergo are nearly unknown. Modification of digestion by age.

Hunger appears to be very acute in children, and not subject to periodic returns, as in the adult; it commences again at such brief intervals, that it appears a continuation: it is at least certain, that it takes place though the stomach is far from being empty. Suction is the mode of taking food which is proper to children; they execute it so much the more easily, as the lips and the tongue are more grown. This action appears in them entirely instinctive, at least for the first months. All mastication is impossible until the appearance of the teeth, and also during a part of the time that the teething continues. If the child compresses the substances introduced into the mouth, it is rather to extract the juice that they contain, and to favour their solution, than to chew them. We presume that the abundance of saliva that children possess, may, to a certain degree, be a substitute for mastication. Mastication in children.

We must pass to the excretion of the feces, in order to have something positive upon the digestion of very young children, compared to that of man; we see that this excretion takes place frequently; that the excrements are almost liquid, and of a yellowish colour; have not that odour which they will have when the child shall begin to use other sorts of food than milk; perhaps at this age the abdominal muscles would not have sufficient energy to expel solid excremental matters.

The incisors, and even the eye-teeth, afford but a very weak mastication to the child; the grinders must have come out to give sufficient force to this action, and even then it is capable of but little exertion upon hard substances; for the elevating muscles of the inferior jaw are too weak, and they are inserted into it too obliquely for substances of a certain hardness to be broken by the teeth.

Mastication does not acquire all the perfection of which it is susceptible, until after the second teething, when the angle of the jaw is well formed. Excepting the modifications occasioned by the wearing, or accidental loss of the teeth, the mastication continues in this state until old age, a period at which it constantly changes, sometimes because the teeth are worn, or partly lost; sometimes by their being all lost, there remain only the edges of the sockets for chewing.

Mastication in old people.

To these causes that render mastication difficult in old age, are added: 1st, the too great extent of the lips, which, as soon as the incisors have come out, have too great a length to go from one jaw to the other, and which, touching on the internal face, instead of the edges, can no longer retain the saliva; 2dly, the diminution of the angle of the jaw, which, in this respect, becomes like that of children, and the curvature of the body of this bone, which forces the aged to chew with the middle and anterior part of the edge of the sockets, the only place where these edges meet; 3dly, the want of the teeth causes the necessity of chewing with the lips in contact: this gives a particular character to mastication at that age.

The action of the muscles that contribute to digestion undergo the same changes that we have mentioned, in speaking of influence of age upon muscular contraction.

These muscles, at first weak in the child, more vigorous and active in youth and adult age, diminish in energy in advanced life, and become very weak in extreme old age. The digestive actions which depend on muscular contraction, go through the same degrees, as may be easily ascertained by examining the manner in which the prehension of aliments, mastication, and the excretion of the feces are executed at different periods of life.

Excretion of feces in old age.

On account of the extreme weakness of the muscles in certain old people who are continually costive, it may become impossible to expel the excrements, which are sometimes accumulated in very great quantity in the large intestine. In this case, recourse must be had to a surgical operation, in order to get rid of them.

We have only some very general data respecting the modifications that the action of the stomach and that of the intestines undergo in different ages: they appear more rapid and easy during the time of growth; they afterwards seem to become more slow: but, of all the vital actions, perhaps they preserve the longest, and, even to the last moments of life, a great activity.

We will not enter into any detail with regard to the modifications occasioned by sex, climate, habit, temperament, and individual disposition. This sort of consideration is, no doubt, very interesting: but, as it relates more particularly to *Hygieine*, we will merely notice that, in many respects, there are almost as many different manners of digestion as there are individuals, and that, in the same person, the digestion frequently suffers many daily changes to such a degree, that one will digest very easily to-day a substance that could not have been digested yesterday.

Relations of Digestion with the Functions of Relation.

A function so important as digestion, and to which such a great variety of different organs contribute, ought to be very intimately connected with the other functions, and particularly with those of relation. This connection indeed exists; it is so very intimate, that, in most animals, the knowledge of one or several of the organs of external life, informs us of the disposition of the digestive organs, and reciprocally, the inspection of a part of the digestive apparatus enables us to know the disposition of the organs of sense and motion.

Relation of digestion with the senses.

The senses inform us of the presence of the aliments, enable us to seize them, to know their chemical and physical properties, and their useful or bad qualities; and as it is particularly under this last relation that it is most necessary for us to appreciate our food, the smell and the taste, to which this examination is subjected, are considered to have more intimate relations with digestion than the other senses. Some authors have classed them with the digestive actions.

Sometimes the aspect, or odour, of food excites the appetite, and disposes favourably the apparatus of digestion; but the same cause may produce a contrary effect, that is, it may suppress hunger, and even occasion a feeling of disgust.

Influence of digestion on the senses.

A moderate appetite generally gives more delicacy and activity to the senses; but if hunger is continued, we have seen above that the senses lose their action, and no longer are able to transmit exact impressions. During the operation of chymification they have less activity, particularly if the stomach is distended by a great quantity of food.

Relations of digestion with muscular contraction.

The relations of muscular contraction with the digestion are not less evident. We have seen how useful the action of the muscles is in the prehension of food, in mastication, deglutition, and in the excretion of the fecal matters; these motions enable us to procure food; they excite the appetite, and, when they are often repeated, they require a greater quantity of nourishment. They are, in their turn, influenced by the digestive phenomena, hunger renders them more weak and difficult; and when the stomach is full of food, particularly in hot countries, and in people of delicate health, there is an inclination to repose, and an almost impossibility to move; but in cold countries, and in robust people, the presence of food in the stomach is, on the contrary, the cause of an increase of force and agility.

The difficulty of speaking, and particularly of singing, after a copious meal, is easily explained; the volume of the stomach prevents the introduction of the air into the chest, and the motions of the diaphragm, and thus presents an obstacle to the production of the voice.

Relations of digestion with the cerebral functions.

The functions of the brain, and those of digestion, are particularly intimate. In certain cases, hunger gives a particular direction to the ideas, it directs them towards food; in other cases, a strong agitation of the mind, violent grief, sudden fear, make hunger cease for several days, and even render digestion impossible to such a degree, that the food formerly introduced into the stomach undergoes no change. How often do we see persons in whom sorrowful affections have destroyed their digestive faculties! Moral satisfaction, cheerfulness, and mirth, on the contrary, favour digestion: great eaters are seldom accessible to sorrow.

Who has not remarked the influence of digestion upon the state of the mind? How many people are incapable of application during digestion? Who knows not the marked effect that the accumulation of the fecal matter has upon the moral disposition?

OF THE ABSORPTION AND COURSE OF THE CHYLE.

The digestive organs would in vain form chyle, were it to remain in the intestinal canal; for in this case there would be no nutrition. The chyle must be transported from the small intestine into the venous system: this transportation is the principal end of the functions we are going to examine.

To preserve as much as possible the method we have hitherto followed in the explanation of the functions, we shall first speak of the chyle in a general manner.

Of the Chyle.

Of the chyle.

The chyle may be studied under two different forms: 1st, when it is mixed with chyme in the small intestine, and has the characters we have described in speaking of the phenomena of its formation; 2d, under the liquid form, circulating in the chyliferous vessels and the thoracic duct.

Of the chyle contained in the small intestines.

No person having particularly engaged in the examination of the chyle during its stay in the small intestine, our knowledge on this point is little more than what we delivered in speaking of the action of this intestine in digestion; to make up for this, the liquid chyle contained in the chyliferous vessels has been examined with great care.

Chyle contained in the lacteal vessels.

Manner of procuring chyle.

In order to procure it, the best manner consists in giving food to an animal, and, when the digestion is supposed to be in full activity, to strangle it, or cut the spinal marrow behind the occipital bone. The whole length of the breast is cut open; the hand is thrust in so as to pass a ligature which embraces the *aorta*, the œsophagus, and the thoracic duct, the nearest to the neck possible; the ribs of the left side are then twisted or broken, and the thoracic duct is seen, closely adhering to the œsophagus. The upper part is detached and carefully wiped to absorb the blood; it is cut, and the chyle flows into the vessel intended to receive it.

The ancients were acquainted with the existence of the chyle, but their ideas of it were very inexact; it was observed anew at the beginning of the seventeenth century; and being, in certain conditions, of an opaque white, it was compared to milk: the vessels that contain it were even named *lacteal vessels*,—a very improper expression, since there is very little other similarity between chyle and milk except the colour.

It is only in modern times, and by the labours of Dupuytren, Vauquelin, Emmert, and Marcet, that positive notions concerning the chyle have been acquired.

We shall give the observations of these learned men, with the addition of our own.

Chyle proceeding from fat matters.

If the animal from which the chyle is extracted has eaten animal or vegetable substances of a fatty nature, the liquid drawn from the thoracic duct is of a milky white, a little heavier than distilled water, of a strong spermatic odour, of a salt taste, slightly adhering to the tongue, and sensibly alcaline.

Chyle, very soon after it has passed out of the vessel that contained it, becomes firm, and almost solid: after some time it separates into three parts; the one solid that remains at the bottom, another liquid at the top, and a third that forms a very thin layer at the surface of the liquid. The chyle, at the same time, assumes a vivid rose colour.

Chyle of matters not containing fat.

When the chyle proceeds from food that contains no fat substance, it presents the same sort of properties, but instead of being opaque white, it is opaline, and almost transparent; the layer which forms at the top is less marked than in the former sort of chyle.

Chyle never takes the hue of the colouring substances mixed in the food, as many authors have pretended. M. Hallé has proved the contrary by direct experiments; I have lately repeated them, and I obtained results exactly the same.

Animals that I had caused to eat indigo, saffron, and madder, furnished a chyle whose colour had no relation to that of the substances.

Of the three substances into which the chyle separates when abandoned to itself, that of the surface, of an opaque white colour, is a fatty body; the solid part is formed of fibrin and a little colouring matter; the liquid is like the *serum* of the blood.

The proportion of these three parts is variable according to the nature of the food. There are species of chyle, such as that of sugar, which contain very little fibrin; others, such as that of flesh, contain more. The same thing happens with the fat matter, which is very abundant when the food contains grease or oil, whilst there is scarcely any seen when the food is nearly deprived of fatty bodies.

The same salts that exist in the blood are found also in the chyle. We will give presently some other details relative to this fluid.

Apparatus of Absorption and of the course of the Chyle.

This apparatus is composed, 1st, of the lymphatic vessels proper to the small intestine, and from their use named *chyliferous;* 2dly, of the *mesenteric* glands; 3dly, of the thoracic duct.

The chyliferous vessels are very small, but very numerous. They arise from small imperceptible orifices at the surface of the *villosities* of the intestinal mucous membrane, and continue to the *mesenteric* glands, in the tissue of which they spread. Chyliferous vessels.

In the sides, and at the surface of the small intestine, these vessels are very slender and numerous; they frequently communicate so as to form a very fine net work; this disposition is particularly visible when they are filled with an opaque white chyle. They enlarge in size and diminish in number as they become more distant from the intestine, and finish by forming isolated trunks that proceed along with the *mesenteric* arteries, and sometimes in the intervals that separate them. In this form they arrive at the *mesenteric* glands.

The *mesenteric glands* are small, irregularly lenticular bodies, the dimensions of which vary from two or three lines to an inch or more. They are very numerous, and placed before the vertebral column, between the two plates of the peritoneum which form the mesentery. Mesenteric glands.

Their structure is still but little known. They receive many blood vessels in proportion to their volume: they are endowed with a vivid sensibility. Their *parenchyma* is of a pale rose colour; its consistence is not very great. In compressing them between the fingers a transparent fluid is extracted, which is inodorous, and has never been examined chemically. It is particularly abundant in the centre of those bodies. I have seen a remarkable quantity in the dead bodies of criminals. The chyliferous and sanguiferous vessels that go into these bodies are reduced to canals of an extreme tenuity, without our being able to Fluid proper to the mesenteric glands.

say how they are disposed. What is certain is, that injections thrown into any of them traverse the tissue of the gland with the greatest facility.

Roots of the thoracic duct.

From the mesenteric glands spring a great number of vessels of the same nature as the *chyliferous*, but generally more voluminous; they are the origins of the thoracic duct. They are directed towards the vertebral column, and attach themselves to the *aorta*, the *vena cava*, &c. They frequently anastomose, and all terminate in the thoracic duct.

Of the thoracic duct.

This name is given to a vessel of the same sort as the preceding, about the size of an ordinary quill, which continues from its commencement in the abdominal cavity, to where it terminates in the left *subclavian* vein. It passes between the pillars of the diaphragm at the side of the aorta; it is then attached to the vertebral column until it is directed to the left *subclavian* vein. Sometimes it has been seen to open into the two *subclavian* veins, and at other times only into the right.

In the interior of the thoracic duct, and the lacteal vessels, there are valves found, so disposed as to permit the fluids to go from the chyliferous vessels towards the *subclavian* vein, but which prevent its return. Their existence is not however constant.

Structure of the chyliferous vessels and of the thoracic duct.

Two membranes enter into the composition of the sides of the chyliferous vessels, and of the thoracic duct; the one internal and delicate, the folds of which form the valves; the other external and fibrous, the resistance of which is much greater than its thinness seems to indicate.

Before passing to the position of the phenomena of absorption and of the course of the chyle, we will make some observations upon the organs by which they are produced.

Chyle of the mucus of the stomach and the saliva.

After twelve, twenty-four, and even thirty-six hours of complete abstinence, the chyliferous vessels of a dog contain a small quantity of a semi-transparent fluid, with a slight milky tinge, and which in other respects presents properties similar to the chyle. This fluid, which is found only in the lacteal vessels and the thoracic duct, and which has never been analyzed, appears to be a chyle which proceeds from the digestion of the saliva, and the mucosities of the stomach: this appears the more probable as the causes which accelerate the secretion of these fluids, such as alcoholic drinks or acids, augment its quantity.

When the privation of all nourishment is prolonged beyond three or four days, the chyliferous vessels become like the lymphatic; they are sometimes filled with lymph, and sometimes empty.

The result of these facts is, that the chyle of the food, extracted from the chyliferous vessels, is always mixed, sometimes with the chyle of the digestive mucus that we have mentioned, sometimes with the lymph; the result is the same if the chyle is extracted from the thoracic duct, for this is always filled with lymph, even after eight days of abstinence.

Thus, then, the matter which has been examined by chemists under the name of *chyle*, ought not to be considered as extracted entirely from alimentary substances; these evidently enter into it only in a certain proportion.

Absorption of Chyle.

However it may happen, the chyle passes from the cavity of the small intestine into the chyliferous vessels. How does this passage take place? At the first view it seems easy to explain such a simple phenomenon; but it is not so. We have seen above that the disposition of the chyliferous vessels is not known; we are not better informed respecting their mode of action: many explanations have, however, been given of it. Thus the absorption of the chyle has been attributed to the capillarity of the lacteal radicles, to the compression of the chyle by the sides of the small intestine, &c. Latterly it has been pretended that it takes place by virtue of the proper sensibility of the absorbing mouths, and of the insensible organic contractility that they are supposed to possess. It is difficult to conceive how eminent men could propose or admit such explanations: they appear to me the expression of the pure ignorance in which we still are with respect to the nature of this phenomenon.

Absorption of chyle.

Mechanism of the absorption of chyle.

It may be useful to add one fact perhaps, which is, that absorption continues a considerable time after death.—After having several times emptied by compression the chyliferous vessels of an animal recently dead, they fill again. This experiment may be repeated several times following; I have sometimes performed it two hours after the death of the animal.

The absorption of the chyle continues several hours after death.

Course of the Chyle.

We have already mentioned the passage of the chyle: it first threads the lacteal vessels, it then traverses the mesenteric glands, it arrives at the thoracic duct, and at last enters the subclavian vein.

Propulsion of chyle.

The causes that determine its motion are the contractility proper to the chyliferous vessels, the unknown cause of its absorption, the pressure of the abdominal muscles, particularly in the motions of respiration, and, perhaps, the pulsation of the arteries of the abdomen.

If we wish to have a correct idea of the velocity with which the chyle flows into the thoracic duct, we must open this canal, as I have done frequently, in a living animal, at the place where it opens into the subclavian vein. We find that this rapidity is not very great, and that it increases every time that the animal compresses the viscera of the abdomen, by the abdominal muscles; a similar effect is produced by compressing the belly with the hand.

Rapidity of the motion of the chyle.

However, the rapidity of the circulation of the chyle appears to me to be in proportion to the quantity formed in the small intestine; this last is in proportion to the quantity of the chyme: so that if the food is in great abundance, and of easy digestion, the chyle will flow quickly; if, on the contrary, the food is in small quantity, or, which is the same thing, if it is of difficult digestion, as less chyle will be formed, so its progress will be more slow.

It would be difficult to appreciate the quantity of chyle that would be formed during a given digestion, though it ought to be considerable. In a dog of ordinary size that had eat animal food at discretion, an incision into the thoracic duct in the neck (the dog being alive) gave about half an ounce of liquid in five minutes, and the running was not suspended during the whole continuance of the formation of the chyle, that is, during several hours.

I do not know if there is any variation in the rapidity of the motion of the chyle during the same digestion; but supposing it uniform, there would enter six ounces of chyle per hour into the venous system. We may presume that the proportion of chyle is more considerable in man, whose chyliferous organs are more voluminous, and in whom the digestion is, in general, more rapid than in the dog.

The blood that flows into the subclavian vein cannot penetrate into the thoracic duct, for there is a valve at its orifice so disposed as to prevent this effect: neither can the chyle flow back into the intestinal canal, on account of the valve of the thoracic duct, and those of the chyliferous vessels.

Action of the mesenteric glands.

Several physiologists think that the chyle undergoes an alteration in traversing the glands of the mesentery; some think that these bodies produce a more intimate mixture of the matters that compose the chyle; others suppose that they add a fluid intended to render the chyle more liquid; there are others again who imagine, on the contrary, that these glands carry away a part of the chyle to purify it. The truth is, the influence of the mesenteric glands upon the chyle is unknown.

Much has also been said about the variable qualities of this liquid, according as the digestion is good or bad, and according to the sorts of food that have been used; the wasting of the body, in certain diseases, has been attributed to the formation of a bad chyle; but the modifications that the chyle undergoes in its composition are very little known. There have also been certain parts of the food spoken of, which, without being changed by the digestive organs, pass with the chyle into the blood; but this is merely a conjecture, supported by no positive experiment.

Doctor Marcet,* who has lately engaged in the examination of the chyle, has compared that from animal matters with that from vegetable matters. He found that the last contains three times more carbon than chyle proceeding from animal food.

Experiments upon the course of the chyle.

We owe to Professor Dupuytren some very ingenious researches, which prove that the thoracic duct is the only direction by which the chyle must pass, in order to serve usefully in nutrition.

We knew by an experiment of Duverney, by certain cases of obstructions of the thoracic duct, and particularly by the experiments of Flandrin, which we shall mention elsewhere; we knew, I say, that the thoracic duct might cease to pour the fluid into the vein with which it joins, without death ensuing. We knew also, it is true, that in certain cases the ligature of the thoracic duct had pro-

* Annales de Chèmie, 1816.

duced death; but the cause of this diversity of results was unknown; the experiments of M. Dupuytren have given a most satisfactory explanation of it. This able surgeon bound the thoracic duct of several horses; some of them died at the end of five or six days; others preserved all the appearances of perfect health. In the animals that died by the ligature, it was always impossible to make any injection pass from the lower part of the duct into the subclavian vein; it is, therefore, very probable that the chyle had ceased to pass into the venous system immediately after the ligature. On the contrary, in those animals that lived, it was always easy to make injections of mercury or other substances pass from the abdominal portion of the duct into the subclavian vein. The injected matters followed the duct to the vicinity of the ligature; they there turned off into voluminous lymphatic vessels which opened into the subclavian vein. It is then evident that in these animals the ligature of the canal did not prevent the chyle from mixing with the venous blood.

Experiments upon the action of the lacteal vessels.

From the chyliferous vessels absorbing the chyle and transporting it into the venous system, people have supposed that they perform the same thing for all the substances that are mixed with the food, and which, though not digested, pass into the blood. For example, most authors say that drinks are absorbed along with the chyle; but as they have made no experiments, upon which to found this opinion, it may be considered as doubtful. I wished to discover how far this could be depended on, and have ascertained, by experiments upon living animals, that in no case do the drinks appear to mix with the chyle. We may prove this by making a dog swallow a certain quantity of alcohol mixed with water while he is digesting food. If half an hour afterwards its chyle is extracted in the manner we have pointed out, we will see that this liquid contains no alcohol, whilst the blood exhales a strong odour of it, and it may be re-produced from the blood by distillation. Similar results are obtained in making the experiment with a solution of camphor, or other odoriferous liquids.

Modifications of the absorption and of the course of the chyle by age, &c. &c.

The modifications that the absorption and flow of the chyle undergo in different ages have not yet been studied; it has only been remarked, that the mesenteric glands change their colour, diminish in volume, and seem to be obliterated in old people. Some authors have concluded that they do not permit the chyle to pass; but this assertion appears too bold, and besides, it is not supported by facts sufficiently proved.

We know nothing of the modifications that this function undergoes by sex, habit, temperament, &c. We are no better informed about the relations that exist between this function and those which we have already explained, or those that remain to be examined.

OF THE ABSORPTION AND COURSE OF THE LYMPH.

We have seen how much remains to be done in order to obtain an exact knowledge of the absorption and flowing of the chyle: the function of which we are now going to give the history, is still less known. Its existence is known in a general manner, but its utility in the animal economy has scarcely been perceived: its most apparent use is to pour the lymph into the venous system. It may be presumed that this phenomenon is only one circumstance of its utility; however, if we do not wish to go beyond what is certain, there are no others to be seen at present.

Of the Lymph.

Nothing proves better the imperfection of science with regard to the function about to be examined than the ideas of physiologists about the lymph. This name is given by some to the serum of the blood, by others to the fluid in the serous membranes; by others, again, to the serosity of the cellular tissue, whilst there are others that consider as lymph that fluid which flows from certain scrophulous ulcers. We think it is necessary to reserve the name of lymph to the liquid contained by the lymphatic vessels and the thoracic duct. It is so much the more necessary to fix the meaning of this word, as, by admitting the other significations, we are apt to give permanence to an opinion which is by no means proved: viz., that the fluids of the serous membranes, of the cellular tissue, &c., are absorbed by the lymphatic vessels, and transported by them into the venous system. Different opinions of the lymph.

Means of procuring lymph.

Two processes may be employed to procure lymph.— One is to lay bare a lymphatic vessel, divide it, and receive the liquid that flows from it; but this is a method difficult to execute, and besides, as the lymphatic vessels are not always filled with lymph, it is uncertain: the other consists in letting an animal fast during four or five days, and then extracting the fluid contained in the thoracic duct, in the manner I have mentioned in speaking of the chyle.

Physical properties of lymph.

The liquid obtained in either way has at first a slightly opaline rose colour. It has a strong spermatic odour; a salt taste; it sometimes presents a slight yellow tinge, and at other times a red madder colour. I am particular in these details, for they have probably occasioned an error in experiments that have been made respecting the absorption of coloured substances.

But lymph does not long remain liquid; it congeals. Its rose colour becomes more deep, an immense number of reddish filaments are developed, irregularly arborescent, and very analogous in appearance to the vessels spread in the tissue of organs.

When we examine carefully the mass of lymph thus coagulated, we find it formed of two parts; the one solid, and forming a great many cells, in which the other remains in a liquid state. If the solid part be separated, the liquid congeals again.

The quantity of lymph procured from one animal is but small; a dog of a large size scarcely yields an ounce. Its quantity appears to increase according to the time of fasting; I also think I have observed its colour become redder when the animal has been longer deprived of food.

Chemical properties of lymph.

The solid part of the lymph, which may be called *clot*, has much analogy with that of the blood. It becomes scarlet-red by the contact of oxygen gas, and purple when plunged in carbonic acid.

The specific gravity of lymph is to that of distilled water as 1022.28 : 1000.00.

I begged M. Chevreul to analyze the lymph of the dog; I gave him a considerable quantity that I had procured by the method above mentioned, after having made dogs fast for some days. I here give the result obtained by this able chemist: 1000 parts of lymph contain—

Water,	926.4
Fibrin,	004.2
Albumen,	61.0
Muriate of Soda,	6.1
Carbonate of Soda,	1.8
Phosphate of Lime, } Phosphate of Magnesia, } Carbonate of Lime, }	0.5
Total,	1000.0

Apparatus of the Absorption and Course of the Lymph.

This apparatus, by its structure and disposition, has the greatest analogy with that of the absorption and flowing of the chyle; or, regarding them in an anatomical point of view, they rather form only one system. It is composed of lymphatic vessels, of glands, or lymphatic ganglions, and of the thoracic duct, which we have already mentioned in treating of the course of the chyle.

Lymphatic vessels exist in almost every part of the body: they are not voluminous, they frequently anastomose, and have almost all a reticular disposition. In the members they form two strata, the one superficial, and the other deep. The first is placed in the cellular tissue, between the skin and the external aponeurosis; it generally accompanies the subcutaneous veins. When the vessels that form this stratum are filled with mercury, the injection of which has succeeded well, they represent a network which surrounds the whole limb. Of the lymphatic vessels.

The deep lymphatics of the limbs are seen principally in the interstices of the muscles, round the nerves and large vessels. The superficial and deep lymphatics are directed towards the superior part of the members, they diminish in number, augment in volume, and very soon enter into the lymphatic glands of the armpit, of the groin, &c., whence they plunge immediately into the abdomen, or the chest. Lymphatic vessels of the limbs.

The lymphatic vessels form also two layers in the trunk, one subcutaneous, the other placed on the internal surface of the sides of the splanchnic cavities. Each viscus has also two orders of lymphatics; the one sort occupy the surface, the other seem to spring from its parenchyma, or internal substance.

These vessels have been hitherto sought for in vain in the brain, the spinal marrow, their envelopes, the eye, the internal ear, &c.

Termination of the lymphatic vessels.

The lymphatic vessels of the trunk and extremities end in the thoracic duct; but those of the exterior parts of the head and the neck terminate, those of the right side in a vessel of considerable size that opens into the right subclavian vein, and those of the left side into a similar vessel, but a little smaller, that opens into the left subclavian vein, a little above the opening of the thoracic duct.

Origin of the lymphatic vessels.

We do not know the form of the lymphatics at their origin; many conjectures, equally ill founded, have been made on this subject. The most plausible is, that they spring from roots extremely fine in the substance of the membranes and of the cellular tissue, and in the parenchyma of the organs, where they appear continuous with the last arterial ramifications. It often happens that an injection thrown into an artery, passes also into the lymphatics that are beside it.

The lymphatics are not regular in their distribution; their volume is now augmented, now diminished; sometimes they are round and cylindric, sometimes they present a great number of swellings placed over each other. Their structure is not sensibly different from that of the chyliferous vessels; they are furnished with valves in the same manner.

Lymphatic glands.

In man, every lymphatic vessel, before reaching the venous system, must traverse a lymphatic gland. These organs, which are very numerous, and which completely resemble the mesenteric glands in form and structure, are found particularly under the armpits, in the sides of the neck, and under the skin of its *nape;* about the lower jaw, in the groin, in the pelvis, in the vicinity of the large vessels. In respect to these, the lymphatic vessels are related exactly as the chyliferous vessels to the mesenteric glands.

Of the Absorption of the Lymph.

Action of the lymphatic vessels.

In order to study the absorption of the lymph with advantage, it is indispensable to examine the received ideas with regard to the origin of this fluid, and the absorbent faculty attributed to the radicles of the lymphatic vessels. We have here much need of caution as well as exactness; for, independently of the difficulty peculiar to the subject, we have to discuss an opinion generally admitted, and supported by the most respectable authorities; but as our only desire is to discover the truth, and not merely to innovate, we hope we shall not give offence by making this inquiry.

Let us first see the origin attributed to lymph. If the best works on this subject are to be believed, the lymph is the result of absorption, exerted by the lymphatic radicles at the surface of the mucous, serous, and synovial membranes, of the plates of the cellular tissue, of the skin, and even in the parenchyma of every organ. Origin of the lymph according to authors.

This mode of considering the subject comprehends two distinct ideas: 1st, that the lymph exists in the different cavities of the body; 2d, that the lymphatic vessels possess an absorbent faculty. The first of these two ideas is quite incorrect, and the other requires a particular examination. Though there is, in fact, an analogy in appearance between the fluids that are seen at the surface of the serous membranes, of the cellular tissue, of the synovial membranes, &c., and the lymph, we will show elsewhere that these fluids are different, both in a chemical and physical point of view; and, as these different fluids differ in themselves, in admitting this origin of the lymph, the different sorts of it ought to have been observed; but, hitherto, the lymph has been found sensibly the same in every part of the body.

Let us now examine the absorbent faculty attributed by authors to the lymphatic vessels.

The liquids introduced into the stomach and intestines are quickly absorbed; the same effect happens into whatever cavity of the economy the liquids are carried: the skin and the mucous surface of the lungs also possess the same property. The ancients, who had remarked several of these phenomena, but who knew nothing of the lymphatic vessels, believed that the veins were the agents of absorption: this belief continued to the middle of the last century, at which time the knowledge of these vessels arrived at considerable perfection. Absorption of the lymphatic vessels.

William Hunter, one of the anatomists who contributed most to the discovery of these vessels, has also insisted most forcibly upon their absorbent power. His doctrine has been propagated and extended by his brother, by his disciples, and generally by all those who have treated of the anatomy of the lymphatic vessels.

The proofs upon which their doctrine is founded by no means possess the value which they attribute to them.

On account of the importance of the subject, we shall enter into some details.

Experiments have been made to establish that the lymphatic vessels are absorbent, and that the veins are not so; but even supposing them exact, which they are very far from being, they are so few in number, that it is astonishing they should have been sufficient to overturn a doctrine anciently established.

Of these experiments, some have been made to prove that the lymphatic vessels absorb, and others to prove that the veins do not absorb. We shall here treat only of the first; the second we shall consider at the article of the *absorption of veins.*

The following experiment was made by *John Hunter*, one of the first who positively denied the absorption of the veins, and admitted that of the lymphatics, and it appeared to him to be very decisive.

Experiments of John Hunter upon lymphatic absorption.

He opened the lower belly of a dog; he emptied several portions of the intestines very quickly of the matters they contained by compressing them sufficiently: he immediately injected hot milk, which he retained by ligatures. The veins that belonged to these portions of the intestines were emptied of their blood by several punctures made in their trunk; he prevented the farther introduction of blood, by applying ligatures to their corresponding arteries, and he then replaced them in the lower belly. He left them there about half an hour. He then took them out, and having examined them carefully, he found that the veins were nearly as empty as when he took them out the first time, and they did not contain a drop of white fluid, whilst the lacteals were quite full.

The imperfect state in which the art of making physiological experiments stood at the period in which John Hunter performed that above, can alone excuse this celebrated anatomist for not having felt how many important circumstances are wanting to give it weight, supposing it to be correct.

Objections to the experiments of John Hunter.

In order that this experiment should have some value, it would be necessary to know if the animal was fasting, or if it was in the operation of digestion when opened; the state of the lymphatics ought to have been examined at the beginning of the experiment: were they or were they not full of chyle?—What changes happened to the milk during the time it was in the intestine? What proof is there that the lacteals were filled with milk at the end of the experiment? Was it not rather chyle with which they were filled? To conclude, this experiment was repeated at different times by *Flandrin*, professor at the veterinary school of Alfort; and though he was well acquainted with the practice of making experiments upon living animals, he was not successful in this, that is to say, he perceived no milk in the lymphatic vessels. I have myself several times repeated this experiment, and the results that I obtained were perfectly the same as those of Flandrin, and consequently quite contrary to those of Hunter.

Thus the principal experiment of an author worthy of credit, in which he supposed he had witnessed the absorption of another fluid besides the chyle, by the lacteals, appears to have been either illusory or insignificant.

I pass the other experiments of J. Hunter in silence, they being less conclusive than this. They have been repeated without success by Flandrin, as well as by myself.*

I thought it necessary to make some trials, in order to determine if the chyliferous and other lymphatic vessels of the intestinal canal really absorb other fluids besides the chyle.

Experiments upon lymphatic absorption.

In the first place, I proved that if a dog is made to swallow four ounces of water, pure or mixed with a certain quantity of alcohol, of colouring matter, of acid or salt, in about an hour the whole of the liquid is absorbed in the intestinal canal.

It was evident that if these different liquids were absorbed by the lymphatic vessels of the intestines they must traverse the thoracic duct; we ought then to find a quantity more or less in this canal, by collecting the lymph of the animals an hour, or three quarters of an hour, after the introduction of the liquids into the stomach.

First Experiment.—A dog swallowed four ounces of a decoction of rhubarb; half an hour after, the lymph was extracted from the thoracic duct. This fluid presented no trace of rhubarb; the half of the liquid had nevertheless disappeared from the intestinal canal, and there was rhubarb perceptible in the urine.

* J. Hunter only employed five animals in the whole course of his experiments upon absorption.

Second Experiment.—A dog was caused to drink six ounces of a solution of prussiate of potass in water: a quarter of an hour after, the urine contained the prussiate very evidently: the lymph extracted from the thoracic duct contained none.

Third Experiment.—Three ounces of alcohol diluted in water were given to a dog; in a quarter of an hour the blood of the dog had a strong odour of alcohol: the lymph had none at all.

Fourth Experiment.—The thoracic duct of a dog having been tied at the neck, he was made to drink two ounces of a decoction of *nux vomica,* a very poisonous liquid for dogs. The animal died as soon as if the thoracic duct had remained untouched. When the body was opened it was ascertained that the canal of the lymph was not double, that it had only one opening into the left subclavian vein, and that it had been well tied.

Fifth Experiment.—The thoracic duct of a dog was tied in the same way, and two ounces of decoction of *nux vomica* injected into the rectum: the effects were similar to what would have happened if the canal had not been tied, that is, the animal died very soon. The disposition of the canal was analogous to that of the preceding experiments.

Sixth Experiment.—Upon a dog that, seven hours before, had eaten a great quantity of meat, in order to make the chyliferous lymphatics easily perceived, M. Delille and I made an incision into the parietes of the abdomen, and we drew out a part of the small intestine, upon which we put two ligatures at 15.75 inches distance from each other. The lymphatics which proceeded from this portion of the intestine were white and very apparent, on account of the chyle by which they were distended. Two new ligatures were placed upon each of these vessels at the distance of two-thirds of an inch, and we cut these vessels between the two ligatures. We ascertained, besides, by every possible means, that the part of the intestine taken from the abdomen had no communication with the rest of the body by the lymphatic vessels. Five arteries, and five *mesenteric* veins came to this intestinal portion; four of these arteries, and as many veins, were tied, and cut in the same manner as the lymphatics; then the two extremities of that part of the intestine were cut and separated entirely from the rest of the small intestine. Thus we had a portion of the small intestine of the length of

15.75 inches, communicating with the rest of the body *only by an artery and a mesenteric vein.*

These two vessels were insulated for four fingers' breadth; we took away the cellular tunic, lest any lymphatics might have remained hid in it. We injected into the cavity of the intestinal part nearly two ounces of decoction of *nux vomica*, and a ligature was placed to prevent the passing out of the injected liquid. The part, after being enveloped in fine linen, was replaced in the abdomen. It was exactly one o'clock; six minutes afterwards the effects of the poison appeared in their usual manner: so that every thing took place as if the peninsulated portion of intestine had been in its natural state.

Experiments upon lymphatic absorption.

I have repeated each of these experiments several times; I have varied them in different ways, and the results were always the same. I think they are sufficient to establish positively that the lymphatic vessels are not the only agents of intestinal absorption, and that they must render it doubtful whether the absorption of these vessels is exerted upon other substances besides the chyle.

It is rather by analogy than upon positive facts that the lymphatic absorption has been admitted in the *genito-urinary* and pulmonary mucous surfaces, in the serous and synovial membranes, in the cellular tissue, at the surface of the skin, and in the tissue of the organs. We will, however, examine the few proofs that authors have brought to support them.

The lymphatic vessels are the only organs of absorption that operate in the intestinal canal: the lymphatic vessels, then, of the rest of the body, the disposition of which is similar, or very analogous, to the chyliferous vessels, ought to possess the same faculty. Such is the reasoning of the favourers of absorption by the lymphatics; and as it is known that all the surfaces, exterior and interior, of the economy absorb, it has been concluded that the lymphatic vessels were every where the instruments of absorption.

If the absorbent faculty of the lymphatics of the intestinal canal were proved for other substances besides the chyle, this reasoning might be very forcible; but as we have just seen that it is perfectly uncertain, we cannot admit it; and we are obliged to have recourse to other facts, or experiments, which, as is generally believed, demonstrate the lymphatic absorption.

Lymphatic absorption of the mucous membranes.

In animals, dead in consequence of pulmonary or abdominal hemorrhage, Mascagni found the lymphatics of the lungs and of the peritoneum gorged with blood; he concluded from this that these vessels had absorbed the fluid by which they were filled: but I have often found, both in animals and in man, lymphatics distended with blood, in cases in which there had been no effusion of that fluid; and besides, there is in certain cases so little difference between the lymph and the blood, that they cannot be easily distinguished. The fact of Mascagni is thus of little importance to the question.

Lymphatic absorption of the serous membranes.

J. Hunter, after having injected water coloured by indigo into the peritoneum of an animal, affirms that he saw the lymphatics filled with a liquid of a blue colour; but this fact has been disproved by the experiments of Flandrin upon horses. This author injected into the pleura and the peritoneum not only a solution of indigo in water, but other coloured liquors, and he never saw them pass into the lymphatics, though they were both very promptly absorbed.

M. Dupuytren and myself have made more than one hundred and fifty experiments, in which we submitted a great number of different fluids to the absorption of the serous membranes, and we never saw them enter the lymphatic vessels.

The substances that are thus introduced into the serous cavities produce very rapid effects on account of the quickness with which they are absorbed. Opium produces drowsiness, wine drunkenness, &c. I have ascertained by several experiments that the ligature of the thoracic duct does not diminish at all the rapidity of these effects. It is, then, very doubtful whether the lymphatic vessels are the organs of absorption in the serous cavities. We may add, that the arachnoid membrane, the membrane of the aqueous humour, the hyaloid membrane, the structure and disposition of which are very analogous to those of the serous membranes, and in which no lymphatic vessel has ever been seen, possess an absorbent faculty quite as active as that of the other membranes of the same class.

Lymphatic absorption of the cellular tissue

When a ligature is applied to a member, and strongly drawn, the part of the member farthest from the heart swells, and the serosity accumulates in the cellular tissue. There happens a similar phenomenon after certain operations for cancer in the breast, in which it is necessary to carry away all the lymphatic glands of the axilla. This phenomenon has been explained by saying that the ligature or removal of the glands of the arm-pit oppose the circulation of the lymph, and particularly its absorption in the cellular tissue. Let us see how far this explanation is satisfactory. In the first place, lymph is a fluid very different from the cellular serosity; then, cannot the accumulation of this serosity depend upon other causes than the obstruction of the absorbent action of the lymphatics; upon the difficulty of circulation, for example, or of the return of the venous blood? Besides, the subtraction of the glands of the arm-pit does not always produce the effect of which we have spoken, and scirrhous obstructions are often seen, and even complete disorganizations of the glands of the arm-pit or groin, that are not accompanied with any œdema.

More numerous proofs are given by authors, of the absorption of the lymphatics situated in the skin. (71)

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(71) To the arguments bearing on lymphatic absorption, here delivered, a few others may be added.

In doing this, we shall not deviate from the laudable brevity of our text. It must, however, be premised, that all parties are agreed on two points: *first*, that the cutis vera enjoys a very high absorbent power: *secondly*, that the internal surface of the lungs, whether covered or not with a thin cuticle, (*Bich. Anat. Gen.* ii. 764.) possesses the same faculty in an eminent degree.

It follows from these two principles, that, in order to ascertain the absorption of a substance brought in contact with the cuticle, it must be determined whether, instead of being drawn in through the cuticle, it may not in reality have been inhaled by the absorbing vessels of the *pulmonary surface*, or by those of the *true skin*. Should it have had an opportunity of passing through either of the latter, the mere absorption of any matter, can afford no proof of *Epidermic inhalation*, which is the true question at issue. In order to investigate this point, M. Seguin devised a very simple experiment. He dissolved muriate of mercury in water, and found that the mercury produced no effect upon the person that bathed in the water, provided no part of the cuticle was injured: but upon rubbing off a portion of the cuticle, the mercurial solution was absorbed, and the effects of the mercury became evident upon the body, labouring at the time under the venereal poison. The cuticle, then, does not absorb this solution; the cutis vera absorbs it freely. In order to render this experiment more complete, it should be repeated with every substance supposed to be absorbable by the cuticle. It is an *experimentum crucis;* since it separates from the idea of superficial absorption, the epidermis, and demonstrates the constant connexion of the true skin with this office. "*Instantiarum crucis,*" says Bacon, "ratio talis est. Cum in inquisitione naturæ alicujus, intellectus ponitur tanquam in æquilibrio, ut incertus sit, utri naturarum e duabus, vel quandoque pluribus, causa naturæ inquisitæ attribui aut assignari debeat, propter complurium naturarum concursum, frequentem et ordinari-

Lymphatic absorption by the skin

A person pricks his finger in the dissection of a putrified body; two or three days after, the puncture inflames,

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um; *instantiæ crucis*, ostendunt consortium UNIUS EX NATURIS, (quoad naturam inquisitam) fidum et indissolubile; alterius autem varium et separabile: unde terminatur quæstio, et recipitur natura illa prior pro causa, missa altera et repudiata. Itaque hujusmodi instantiæ sunt maximæ lucis, et quasi magnæ auctoritatis;" &c.—*Nov. Org.* ii. 36. A similar *experimentum crucis* was instituted by Dr. Klapp, and also by Dr. Dangerfield, both Americans, in order to determine the share of the pulmonary membrane in superficial absorption of volatile substances. They immersed the arm in oil of turpentine for twenty or more minutes, and on examination, the urine was now found to exhibit the well-known signs of the presence of turpentine in the system. Even remaining for a time in the same room with the oil of turpentine, produced the same effect. They now repeated the experiment, after a sufficient interval, with this difference, that the arm was passed into the vessel containing the oil, through an air-tight aperture in a door, so contrived that the experimentalist could not receive any of the vapour of the volatile substance into his lungs. After persevering in this position for half an hour, the urine exhibited no change whatever. Hence they conclude, that in the former, and all similar cases, the turpentine must have entered the system by the pulmonary membrane.

As these and the foregoing experiments were fairly made, and with substances not by any means unfavourable to the theory of epidermic inhalation, but which may very well represent the fixed and volatile bodies yet untried, the question may be considered as at rest with respect to simple cuticular absorption; at least till these experiments have been contradicted. See *Seguin Medicine Eclairée*, III. 238. *Klapp. Chem. Phys.* (1805). *Dr. Kelly*, in *Ed. Med. and Surg. Journal, April*, 1805. *Dr. Nathan Young's Thesis de Cutis Inhalatione, Edin.* 1818. The two latter authors have defended the cutaneous absorption with much ability. Though, from having been present at them all, I can vouch for the good faith with which the experiments of Dr. Young were performed; yet it may certainly be objected to them, that his nostrils were not stopped during their progress: but this is merely a possible source of fallacy. It is much more likely that his, and most other experiments, supposed to prove cutaneous absorption, are correct in their details, and that their true explanation is to be found in the capillary porosity, or sponginess of the epidermis, by which a considerable addition must be made to our weight every time we enter the bath. The simple imbibition of 15 square feet of porous surface must always be considerable; still more when aided by the high temperature at which the bath is commonly entered.

Nay, the occasional penetration of mercury, sulphur, cantharides, &c., through the cuticle by friction, or otherwise, is subject to a similar explanation. If, in solution, they are soaked, in the progress of long maceration, through the whole thickness of the cuticle, and when arrived at the cutis vera, what forbids their now entering its absorbents, in the same way as they would after inoculation? Besides, the violence of friction, or the acrimony of their own nature, may often force substances through the cuticle which would not have reached it by simple imbibition. Hence, in mercurial friction, it often becomes necessary to increase the force employed, and even to soften the too dense cuticle, by soaking it with soap and water—a process which could only operate unfavourably on the orifices of lymphatics. Lastly, by far the greater number of proofs advanced, depend the corresponding glands of the arm-pit swell, and become painful. In certain circumstances, not very common, these effects are accompanied with a vivid redness, and a trifling pain, in the whole length of the lymphatic trunks of the arm. It is then said that the putrified animal matter has been absorbed by the lymphatics of the finger, that it has been transported by them to the glands of the arm-pit, and that its passage has been every where marked by the irritation and inflammation of the parts traversed.

Objections to the proofs of the lymphatic absorption by the skin

Appearances are certainly favourable to this explanation, and I do not deny its validity; I even incline to believe that hereafter it will be found exact: but when we consider that it is now one of the bases of Therapeutics, and that it often decides the employment of energetic medicines, I think that, in this respect, doubt cannot be carried too far. I shall therefore make the following observations upon this explanation. Very frequently one is pricked with a scalpel impregnated with putrid matter, without any accident happening. Very frequently, a puncture made with a needle that is perfectly clean produces the same phenomena: a slight contusion upon the end of the finger produces often similar effects. The impression of cold upon the feet often causes a swelling in the glands of the groin, and redness in the lymphatics of the internal part of the leg and the thigh. It may be added, that inflammation of the veins by a puncture is frequently seen, and even at the same time with the lymphatics. I saw a striking and very unfortunate example of it upon the dead body of Professor Lecler. This excellent man died in consequence of the absorption of putrid miasms, which took place by a small excoriation of one of the fingers of the right hand. The lymphatics and the

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not on superficial, but pulmonary absorption; a fact now well known to the jockeys of Newmarket. Captain Bligh's instance is merely one of numerous examples which might be quoted, of the sympathy between the skin, and its continuation into the fauces, œsophagus, and stomach.

The fact, then, of cuticular absorption may be stated as follows: *The cuticle has no absorbing orifices opening on its surface, and the substances hitherto supposed to be taken up by these, really make their way into the body, by the action of the absorbing vessels of the lungs and cutis vera: yet, from the imbibing faculty common to the cuticle with dead or inorganized matter, many substances may, by long* MACERATION, OR EXTERNAL VIOLENCE, *find a passage through it to the absorbing orifices of the cutis vera, without any laceration of the cuticle being visible.*

glands of the arm-pit were inflamed; these glands had a sickly brownish colour; but the internal membrane of the veins of the right arm presented unequivocal traces of inflammation, and the lymphatic glands of the whole body exhibited the same alteration as those of the right arm-pit.

Lymphatic absorption by the skin

Several facts of Pathology are also considered as a proof of lymphatic absorption. After impure coition, an ulcer comes out on the *glans penis*, and some days afterwards the glands of the groin swell and become painful; or these same glands inflame without any previous ulceration upon the penis. This swelling frequently happens in the first days of a gonorrhœal discharge. In these different cases, the swelling of the glands is attributed to the absorption of the *venereal virus*, which, they say, has been caught by the lymphatic orifices, and transported to the glands. Also, because the swelled glands of the groin return sometimes to their natural state, after mercurial frictions upon the internal part of the corresponding thigh, it has been concluded that the mercury is absorbed by the lymphatics of the skin, and that it traverses the glands of the groin. These different facts are really of such a nature as to make us suspect absorption by the lymphatic vessels; but they do not demonstrate it to a certainty. This will never be completely demonstrated until the substance supposed to be absorbed is found in these vessels; and as in those cases mentioned, neither the pus of the venereal ulcers and gonorrhœas nor the mercury, have been seen in the lymphatic vessels; they therefore give no proof of lymphatic absorption. And what is more, even should pus, mercurial ointment, or any other substance used in friction, be found in these vessels, it would be necessary to prove that it was by absorption they entered. We will see, farther on, with what facility substances mixed with the blood pass into the lymphatic system.

Mascagni cites an experiment he made upon himself, and which he considers the most convincing; I here give a literal translation of it: "Having kept my feet plunged in water for some time, I observed upon myself a somewhat painful swelling of the inguinal glands, and a transudation of fluid through the gland. I was afterwards seized with a fluxion of the head; a sharp and salt fluid flowed from my nostrils. I thus explain these phenomena. When an extraordinary quantity of fluid filled the lymphatics of the feet, and the inguinal glands were swelled with it, the lymphatics of the penis were more difficultly loaded with it. The blood vessels continued to separate the same quantity of fluid; but the lymphatic vessels could not carry it wholly away, for the motion of their own fluid was retarded: on this account the remainder of the fluid secreted, transuded through the gland. Also, by the abundant absorption of the lymphatics of the feet, the thoracic duct was distended with great force, the lymphatics of the pituitary membrane could no longer freely absorb the fluids deposited upon the surface; and thence *coryza*." By this experiment we learn that Mascagni had the glands of the groin swelled, after his feet had remained some time in the water; the explanation which follows is quite hypothetical.

It is also by induction alone, that absorption in the centre of the organs is admitted: it is supported by no experiment; and the facts that are given as proofs, such as metastasis, the resolution of tumours, the diminution of the volume of organs, &c., establish that there is an interior absorption, but they do not prove that it is executed by the lymphatic vessels.

Observation relative to lymphatic absorption.

I must cite a fact, which, in my opinion, is much more favourable to the doctrine of absorption by the lymphatic vessels than any that I have hitherto mentioned: we owe it to M. Dupuytren.

A woman that had a large tumour upon the superior and internal part of the thigh, with fluctuation, died at the *Hotel Dieu*, in 1810. A few days before her death, an inflammation was seen in the subcutaneous cellular tissue, at the internal part of the tumour.

The body was opened next day by M. Dupuytren. Scarcely had he divided the skin which covered the tumour, when there were formed white points upon the lips of the incision. Being surprised at this phenomenon, he dissected the skin to a certain extent with care, and he saw the subcutaneous cellular tissue overspread by white lines, some of which were as large as crow quills. They were evidently lymphatic vessels filled with a puriform matter. The glands of the groin into which these vessels passed, were filled with the same matter; the lymphatics were filled with the same matter up to the lumbar glands; but neither these glands nor the thoracic duct presented any trace of it.

Reflections.

Now, the question is to know if we may conclude from this fact, that the lymphatics *had absorbed* the fluid by which they were filled: this is probable; but, in order to prove it, it would have been necessary that the fluid contained by the lymphatics, and that of the pus that filled the cellular tissue, had been proved to be the same. But they who inspected it were satisfied with the appearance. M. Cruveilhier, who relates this fact, expresses himself thus:—"I have said that the liquid was pus; it had the opacity, the white colour, and the consistence of it." Now, in similar circumstances, the appearance alone is so deceiving, that it ought not to be trusted. By following this method, have not milk and chyle, two liquids which are very different, long been confounded, simply because their appearance is the same? But are we sure that the pus did not come from the lymphatics themselves, which were inflamed, as happens sometimes to the veins?

In many circumstances analogous to that which I have cited, that is, after erysipelatous inflammation with suppuration of the cellular tissue of the limbs, I have seen no trace of purulent matter in the lymphatic vessels; and, besides, it is not extraordinary in cases of this kind to find the veins that spring from the sick parts filled with a matter very analogous to pus.

To return to the absorbent faculty of the lymphatics, we think it may possibly exist, but that is far from being demonstrated; and as we have a great number of facts that appear to establish positively the absorption by the venous radicles, we shall postpone the history of the different absorptions to the period at which we treat of the circulation of venous blood.

Probable origin of the lymph.

We now return to the origin of the lymph admitted by Physiologists. If, on the one hand, the fluids that are supposed to be absorbed by the lymphatic vessels, are different from the lymph in their physical and chemical properties; if, on the other hand, the absorbent faculty of the lymphatic vessels is a phenomenon, the existence of which is very doubtful, what must we think of the received opinion with regard to the origin of the lymph? Is it not plain that it has been lightly admitted, and that there is very little probability in its favour?

Whence, then, comes the fluid that is found in the lymphatic vessels? or, in other terms, what is the real or probable origin of the lymph? In considering, 1st, the nature of the lymph, which has the greatest analogy with the blood; 2dly, the communication demonstrated by anatomy, between the termination of the arteries and the radicles of the lymphatics; 3dly, the facility and quickness with which colouring or saline substances introduce themselves into the lymphatic vessels, it becomes, in my opinion, very probable that the lymph is a part of the blood, which, in place of returning to the heart by the veins, follows the course of the lymphatic vessels.

This is not a new idea; it is nearly the same as that of the anatomists who first discovered the lymphatic vessels, and who supposed that these vessels were intended to carry back to the heart a part of the serum of the blood.

The present discussion upon the origin of the lymph may appear a little too long; but it was indispensable in order to avoid false opinions upon the absorption of this fluid.

We must indeed have quite a different idea of it from that which is found in various physiological authors, who consider it merely as the introduction of lymph into the lymphatic radicles. But what obscurity surrounds this phenomenon! we are ignorant of its cause, of its mechanism, of the disposition of the instruments by which it is performed, and even of the circumstances under which it takes place. Indeed it seems to be only in particular cases that the lymphatics contain any lymph. This obscurity ought not to surprise us; we have already seen, and we shall have occasion to see again, more than once, that it reigns over all the phenomena of life to which we cannot apply the laws of physics, mechanics, or chemistry, and consequently over all those that relate to vital actions, or to nutrition. Absorption of lymph.

Course of the Lymph.

We have but little to say respecting the course of the lymph; authors scarcely mention it, and that in a very vague manner, while our own observations on this subject are far from being numerous. This would be a new and interesting subject of research. Course of the lymph.

According to the general disposition of the lymphatic apparatus, the termination of the thoracic duct, and of the cervical trunks in the subclavian veins, the form and arrangements of the valves, we cannot doubt that the lymph flows from the different parts of the body from which the lymphatics arise towards the venous system; but the particular phenomena of this motion, its causes, variations, &c., have not yet been studied. The few remarks that I have had leisure to make in this respect are these.

Observations upon the course of the lymph.

A. In man and living animals, the lymphatics of the extremities, of the head, and the neck, rarely contain any lymph; but their interior surface appears lubricated only by a very thin fluid. However, in certain cases the lymph stops short in one or several of these vessels, distends them, and gives them a similar appearance to varicous veins, except the colour.

M. Soemmering has seen several of them in this state, upon the dorsum of the foot of a woman, and I have had occasion to observe one surrounding the *corona glandis.*

In dogs, cats, and other living animals, lymphatic vessels are more frequently found full of lymph on the surface of the liver, of the gall-bladder, and of the vena cava inferior, of the vena porta, in the pelvis, and upon the sides of the vertebral column.

The cervical trunks are also frequently filled with lymph; however, it is not extraordinary to find them without it. With regard to the thoracic duct, I never found it empty, even when the lymphatic vessels of the rest of the body were in a state of complete vacuity.

B. Whence these varieties in the presence of the lymph in the lymphatic vessels? why do those of the abdomen contain it oftener than the others? and why does the thoracic duct contain it always? I believe it impossible at present to reply to any of these questions. The only fact which I think I have observed, but which I would not warrant, is, that the lymph is more frequently found in the lymphatic trunks of the neck, when animals have been long deprived of all food or drink.

C. According as abstinence is of longer continuation in a dog, the lymph becomes redder. In some, that had fasted eight days, I have seen it nearly of the colour of blood. In these cases, its quantity has also appeared to me more considerable.

D. Lymph appears to move slowly in its vessels. If a puncture is made in one of them in a living man, (I have had occasion to perform this only once) the lymph flows but slowly and without forming a jet. M. Soemmering made a similar observation some time previously.

When the lymphatic trunks of the neck are full of lymph, they may be easily isolated for more than the distance of an inch. The liquid with which they are filled may then be observed to flow very slowly. If they are so compressed as to make the lymph with which they are distended pass into the subclavian vein, it requires sometimes half an hour before they fill again, and they often remain empty.

E. The lymphatic vessels are nevertheless evidently contractile; they often empty themselves when they are exposed to the air. Probably the reason why they are almost always found empty, not even excepting the thoracic duct, in animals recently dead, is because they have contracted. This faculty is, no doubt, one of the causes which determine the introduction of lymph into the venous system. The pressure that the lymphatics support by the effect of contractility of tissue from the skin and other organs, from muscular contraction, the pulsation of the arteries, &c., ought to be taken into account in explaining the progress of the lymph. This seems evident with respect to the lymphatics contained in the abdominal cavity.

Uses of the lymphatic glands.

F. The use of the lymphatic glands is completely unknown, and, perhaps, it is for this reason they have been the object of so many hypotheses. They were considered by Malpighi as so many *little hearts* which gave to the lymph its progressive motion; other authors have advanced that they served to strengthen the *subdivisions* of the lymphatic vessels, to *imbibe* the superfluous humours like *spunges*, to give a *nourishing juice to the nerves*, to *furnish the fat*, &c.; indeed every one has given free scope to his imagination.*

We will say no more upon the motion of the lymph; it must be seen how much remains to clear up this phenomenon, and in general to investigate all those which relate to the functions of the lymphatic system, and to its utility in the animal economy.

* I omit, designedly, the *retrograde motion* of the fluids in lymphatic vessels: what Darwin, and others, have written upon that subject seems quite fanciful. (72)

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(72) See some valuable observations on this subject, in Dr. R. L. Milligan's inaugural dissertation, *De potu assimilando*.

If our positive knowledge on this subject is so limited, what confidence can be given to medical theories that treat of the thickening of the lymph, of the obstruction and difficulty of the lymphatic glands, of the want of action of the absorbent lymphatic orifices, occasioning dropsies, &c.; and how can we determine to administer remedies, which are sometimes violent, according to ideas of this kind?

The changes of structure and volume which happen to the lymphatic glands in the progress of age, may make us presume that the action of the lymphatic system undergoes modifications in the different periods of life; but nothing certain is known in this respect.

COURSE OF THE VENOUS BLOOD.

The intention of the function we are about to study, is to transport the venous blood from every part of the body to the lungs.

Besides, the organs by which it is performed, are at the same time the principal agents of absorption, either in the exterior or interior of the body; the absorption of the chyle, of the lymph, and that which takes place at the mucous surface of the lungs, being excepted.

Of the Venous Blood.

This name is given to the animal liquid contained in the veins, the right side of the heart, and the pulmonary artery; organs which, by their union, form the apparatus proper to the circulation of venous blood.

Physical properties of venous blood.

This liquid is of a dark red colour, so deep that the epithet of *black blood* has been given to it: its colour is less deep in certain cases, and perhaps even scarlet. Its odour is insipid, and *sui generis*; its taste is also peculiar; however, it is known to contain salts, and principally the muriate of soda. Its specific gravity is a little more than that of water. Haller found its *medium* as 1.0527 : 1.0000. Its capacity for caloric may be expressed by 934,(73) that

(73) Our author seems to prefer the first of Dr. Davy's results in this place, and the last of the table of the differences of arterial and venous blood. The mean of all the experiments is, arterial blood to venous blood

of arterial blood being 921. Its mean temperature is 31 degrees of Reaumur, = 102 F.

Coagulation of venous blood.

Venous blood, being extracted from its proper vessels, and left to itself, in a short time forms a soft mass; this mass separates spontaneously into two parts, the one liquid, yellowish, transparent, called *serum:* the other soft, almost solid, of a deep brown red, entirely opaque: this is the *cruor*, or *clot*. This occupies the bottom of the vessel; the serum is placed above. Sometimes a thin layer forms at the top of the serum, which is soft and reddish, and to which has been very improperly given the name of *rind*, *buff*, or *crust* of the blood.

This spontaneous separation of the elements of the blood does not take place quickly, except when it is in repose. If it is agitated it remains liquid, and preserves its homogeneity much longer.

Chemical properties of the blood.

If the venous blood is placed in contact with the atmosphere, or with oxygen gas, it takes a vermillion red colour; with ammoniac it becomes cherry red; with azote a deeper brown red, &c.* In changing colour it absorbs a considerable quantity of these different gases; it exhales a considerable quantity of carbonic acid, when kept some time under a bell upon mercury. M. Vogel has recently made some new researches on this subject.†

Composition of the serum.

According to M. Berzelius, 1000 parts of the serum of human blood contain—

Water,		903.0
Albumen,		80.0
Substances soluble in alcohol	Lactate of soda and extractive matter, 4; Muriates of soda, & potass 6	10.0
Substances soluble in water	Soda and animal matter, Phosphate of soda, 4; Loss, 3	7.0
	Total,	1000.0

The serum sometimes presents a whitish tint, as if milky, which has made it be supposed that it contained chyle: it

* For the changes of colour from other gases, see Thenard's Chemistry, vol. iii. p. 513.

† Annales de Chèmie, 1816.

as 900 : 872. It was—I. Exp. 934, A. : 921, V. II. Exp. 814, A. : 812, V. III. 913, A, : 903, V. IV. 839. A. : 852, V. Mean 900, A. : 872, V.

appears to be a fatty matter which gives it this appearance.

The *clot* of the blood is essentially formed of *fibrin,* and *colouring matter.*

Chemical composition of the clot.

The fibrin, separated from the colouring matter, is whitish, insipid, and inodorous; heavier than water, without action upon vegetable colours, elastic when humid, it becomes brittle by being dried.

In distillation it gives out a great deal of carbonate of ammonia, and a vast quantity of carbon, the ashes of which contain much phosphate of lime, a little phosphate of magnesia, carbonate of lime, and carbonate of soda. A hundred parts of fibrin are composed of—

Carbon, - - - - - - - - - - -	53.360
Oxygen, - - - - - - - - - -	19.685
Hydrogen, - - - - - - - - - -	7.021
Azote, - - - - - - - - - - -	19.934
Total, - - - - -	100.000

Colouring matter of the blood.

The colouring matter is soluble in water and in the serum of the blood. Examined with the microscope in solution with these liquids, it appears like most fluids of the animal economy, formed of small globules; (74) dried and calcined in contact with the air, it melts and swells up, burns with flame, and yields a coal that is difficultly re-

(74) The globules of the blood when measured by a micrometer, are estimated about $\frac{1}{5000}$ of an inch in diameter.—*See Sir E. Home's* paper, Phil. Trans. 1819. But whether they are of any regular, well-defined figure, or whether they wear their coating of colouring matter inside or out, must remain undetermined, till future improvements in the microscope render the results of that instrument in objects of their diameter so uniform, that no further room for doubting remains. At present they are so discordant that no name or authority whatever can sanction our giving a preference here to any one of them. They have been compared to a globe, to a bladder with a pea in it, to a piece of money, to a drum, to a candlestick, to a hexaedron, and I know not what else. The globules are the staple commodity, the *ferae naturae,* of physiological advertisers. Home's researches were, he says, dictated by his friend Bauer, observing the growth of the roots of wheat being produced from the expansion of carbonic acid; and he finishes his paper by concluding that human vessels are formed in the same way, namely, by the channels it forms during its escape from the coagulate lymph in which alone new vessels can be formed. Now, it is quite true that carbonic acid has been detected copiously, both in the BLOOD and URINE, and probably always exists there: but it is not easy to show in what manner its channels, such as appear in starch and sowens, can ever be condensed into organized tubes.—*See Edin. Med. and Surg. Journal, Vol. XV.*

duced to ashes. This coal furnishes, during its combustion, ammoniacal gas, and it gives the hundredth part of its weight of ashes, composed nearly of—

Oxide of Iron,	55.0
Phosphate of Lime, with Phosphate of Magnesia, a trace	8.5
Pure Lime,	17.5
Carbonic Acid,	17.5

Chemical composition of the blood.

It is of importance to remark, that in none of the parts of the blood are any gelatine or phosphate of iron found, as was at first supposed.

The respective relations in quantity of the serum to the coagulum, and those of the colouring matter to the fibrin, have not yet been carefully examined. It is to be presumed, as we shall see afterwards, that they are variable according to an infinity of circumstances.

Causes of the coagulation of the blood.

The coagulation of the blood has been, by turns, attributed to refrigeration, to the contact of the air, to the state of repose, &c.; but J. Hunter and Hewson have demonstrated by experiments that this phenomenon cannot be attributed to any of these causes. Hewson took fresh blood and froze it, by exposing it to a low temperature. He afterwards thawed it: the blood appeared fluid at first, and shortly afterwards it coagulated as usual. An experiment of the same kind was made by J. Hunter, with a similar result. Thus, blood does not coagulate because it is cooled. It even appears that a temperature a little elevated is favourable to its coagulation. We also know by experience that the blood thickens when it is deprived of the contact of the air, and agitated; its coagulation is, however, generally favoured by repose and the contact of the air.

But, instead of attributing the coagulation of the blood to any physical influence, on the contrary, it ought to be considered as essentially vital; that is, as giving a demonstrative proof that blood is endowed with life. We shall very soon see of what importance this property of coagulation possessed by the blood, and other liquids, is in many phenomena of nutrition.

Phenomena of the coagulation of the blood.

To obtain a more precise idea of the coagulation of venous blood, I placed a drop of this fluid in the focus of a compound microscope. It appeared like a red mass as long as it was liquid; but the edges became transparent and granular as soon as it began to coagulate; the solid part, almost opaque, formed an infinity of little meshes, or cells, that contained the liquid portion, which was much more transparent: this disposition gave the granular appearance to the edge of the drop of blood. The meshes gradually became larger by the contraction of the solid parts; in many parts they disappeared entirely, and there remained between the exterior circumference of the drop of blood, and the edge of the central clot, only arborizations, quite similar to those that we have described in the lymph. Their divisions communicated with each other like those of the vessels or nerves of leaves. These observations must be made with a diffuse, or artificial light, for the direct light of the sun dries it without producing coagulation.

In many circumstances, blood coagulates though contained in its own proper vessels; but, in general, this phenomenon belongs to a state of sickness.

Some authors thought they had remarked that blood became hotter by coagulation; but J. Hunter, and, recently, M. J. Davy, have proved that there is no elevation of temperature. (75)

Experiments upon the fibrin of the blood.

At the period when galvanism was much treated of in France, it was advanced that, taking a portion of clot recently formed, and submitting it to a galvanic current, it was seen to contract like muscular fibres: I have often tried to produce this effect, by submitting to the action of the pile portions of coagulum at the instant of formation; but I never saw any thing of this kind. I varied these trials in different ways without success. I lately repeated this experiment along with M. Biot, and the result was the same.

The elements of venous blood, such as we have noticed, are known by its analysis; but as all the matters absorbed from the intestinal canal, the serous membranes, the cellular tissue, &c., are immediately mixed with the venous blood, the composition of this liquid must vary in proportion to the matter absorbed. There will be found in it, in different circumstances, alcohol, ether, camphor, and salts, which it does not usually contain, &c., when

(75) Dr. Gordon, who had been deceived into this opinion by his raising the thermometer to the upper part of the fluid, into which stratum, on the principle of circulation, the warmer blood had ascended by its levity; came afterwards to be fully sensible of the justice of Dr. Davy's correction.

these substances have been submitted to absorption in any part of the body.

The greater or less rapidity with which the blood freezes, the solidity of the coagulum, the separation of the serum, the formation of an albuminous stratum at its surface, its particular temperature, either in the vessels or out of them, &c., are so many phenomena that we shall examine when at the article *Arterial Blood.*

APPARATUS OF CIRCULATION OF THE VENOUS BLOOD.

This apparatus is composed, 1st, *Of Veins;* 2dly, *Of the right Auricle and Ventricle of the Heart;* 3dly, *Of the Pulmonary Artery.*

Of the Veins.

The dispositions of the veins in the tissue of the organs cannot be traced by the senses. Of the veins.

When they are first seen they appear in the form of an excessive number of small canals of an extreme tenuity, frequently communicating with each other, and forming a sort of nets with small meshes; the veins soon augment in volume, preserving the reticular form. In this way they form vessels, of which the capacity, the form, and disposition, vary according to each tissue, and even according to each organ.

Some organs appear almost entirely formed of venous radicles: such are the spleen, the *corpora cavernosa penis,* the *clitoris,* the *mamilla,* the iris, the urethra, the *glans penis, &c.* When an injection is thrown into one of the veins which proceed from the different tissues, they are completely filled with the injected matter; which rarely happens, when an injection is thrown into the arteries. An incision in the same parts in man or in the living animals produces a flow of blood which has all the appearances of venous blood.

The venous extremities communicate with the arteries and lymphatic vessels: anatomy removes every doubt in this respect; but those extremities, the disposition of which is unknown, appear also to open at the different surfaces Origin of the veins.

of the membranes, of the cellular tissue, and even in the parenchyma of the organs.

M. Ribes having injected mercury into one of the branches of the *vena porta*, he saw the villi of the intestinal mucous membrane become filled with this metal, and it afterwards passed into the intestinal cavity. In blowing air into the veins from trunks to branches, and forcing the resistance of the valves (which is very easy in dead bodies in which putrefaction has begun,) the same anatomist always saw the air open with the greatest facility into the cellular tissue, though there was no sensible rupture in the sides of the veins. I have made similar remarks in injecting air or other fluids into the veins of the heart. These facts, which were before my experiments upon the absorption of the veins, and which I shall soon mention, agree perfectly well with them.

The veins of the brain surround it every where, form a great part of the *pia mater*, penetrate into the ventricles, where they contribute to the formation of the *plexus-choroides*, and the tela choroides; those of the testicle represent a very fine network, which covers the spermatic vessels; those of the kidneys are short and large.

Passage of the veins.

The veins, abandoning the organs in their direction towards the heart, effect other dispositions which are very different. In the brain they are lodged between the plates of the dura mater, are protected by them, and have the name of *sinus*. In the spermatic cord they are flexuous, they frequently anastomose, and form the *corpus pampiniforme*. Around the vagina they constitute the corpus retiforme. In the uterus they are very voluminous, and present frequent tortuosities. In the members, in the head and the neck, they may be divided into those which are deep and those which are superficial; the one sort accompany the arteries, the others are placed immediately under the skin, amongst the lymphatic trunks that are there.

In proportion as the veins remove from the organs and approach the heart, their number diminishes, and they increase in size, so that the innumerable veins of the body all terminate in the right auricle of the heart, by three trunks, the superior and inferior *vena cava*, and the *coronary vein*.

Anastomoses of the veins.

I said that the small veins communicate with each other by frequent *anastomoses:* this disposition also exists in the large veins and in the venous trunks.

The superficial trunks of the members communicate with the deep veins, the exterior veins of the head with those of the interior, the external jugulars with the internal, the superior vena cava with the inferior, &c. These anastomoses are advantageous to the flowing of the blood in these vessels.

Many veins present in their cavity folds of a parabolic form, called *valves*. They have two edges and two faces free, the one edge adheres to the side of the vein, the other is at liberty. The first is farthest from the heart, the other nearer.

The number of valves is not every where the same.—They are generally more numerous where the blood flows contrary to the force of its own weight, where the veins are very extensible, and have only a slight pressure to support from the surrounding parts: on the contrary, they are wanting in those parts where the veins are exposed to a habitual pressure that favours the circulation of the blood, and in those that are contained in canals that are not extensible. They are rarely found in veins that have less than a line in diameter. Sometimes the valves are so great as entirely to shut the canal represented by the vein; and at other times, they are evidently too small to produce this effect. Anatomists thought that this disposition depended upon the primitive organization; but Bichât thinks that it depends entirely upon the state of pressure or dilatation of the veins at the instant of death.

I have endeavoured to ascertain the accuracy of Bichât's idea, but I own that I cannot possibly believe it. I have not found that the distension of the veins has any influence upon the size of the valves; on the contrary, it appears to remain always the same, but the form changes by the state of pressure or dilatation, and this probably deceived Bichât.

The sides of the veins are formed of three interposed membranes; the outer one is cellular, dense, and difficult to break. If we can believe anatomical works, that which follows is formed of fibres placed in a parallel direction along the vessel, and so much the more easily seen, as the vessel is larger and more contracted. I have vainly endeavoured to discover the fibres of the middle membrane of the veins; I have always observed filaments extremely numerous, interlaced in all directions, and which take the appearance of longitudinal fibres when the vein is gathered up length-ways,—a disposition which is frequently seen in the large veins.

The subcutaneous veins of the members, the sides of which are very thick, are those in which the disposition of this membrane may be studied with most facility.

The chemical nature of the fibrous layer of the large veins is unknown. According to some trials, I suspect that it is fibrinous. It is extensible and resisting; in other respects, it presents no property in the living animal that can make it any thing like the muscular fibres. Being irritated with the point of a scalpel, submitted to a galvanic current, &c., it presents no sensible contraction.

The third membrane of the veins, or the internal tunic, is extremely thin, and very smooth upon the surface which is in contact with the blood. It is very flexible, very extensible, and it nevertheless presents a considerable resistance; for example, it supports without breaking the pressure of a strongly drawn ligature.

Some veins, such as those of the cerebral sinuses, the venous canals of the bones, the superhepatic veins, have their sides formed by this membrane only, and they are almost entirely deficient of the two others.

Physical properties of the veins.

The three tunics united form a very elastic tissue. In whatever direction a vein is stretched, it assumes immediately its primitive form, and I do not know upon what foundation Bichât advanced that they do not possess elasticity: it is very easy to ascertain that they possess this property in a very high degree.

A considerable quantity of small arteries, of small veins, and some filaments of the great sympathetic, are spread over the veins; they are also subject to morbid derangements which happen in the animal economy. They sometimes appear inflamed. (76)

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(76) The inflammation of veins has, of late, been much canvassed by the profession, on account of the numerous deaths from their puncture in bleeding and dissection. Little, however, has transpired that can either explain the affection, or promote its cure. Dr. Duncan, jun., who has for some time considered the subject with the serious attention it merits, maintains, that the inflammation is frequently, not in the tunics of the vein, but in the cellular membrane, which envelops it. The subject, however, is not exactly Physiological.

Of the Right Cavities of the Heart.

Right auricle of the heart.

The heart is too well known for it to be necessary to insist long upon its form and structure. I will merely notice the principal circumstances. In man, in mammiferous animals and birds, it is formed of four cavities, two superior, or auricles, and two inferior, or ventricles. The left auricle and ventricle belong to the apparatus of the course of the arterial blood; the right auricle and ventricle make a part of that of the venous blood.

The form of the right auricle is difficult to explain: its greatest diameter is transverse; its cavity presents behind the orifices of the two *venæ cavæ*, and that of the coronary vein: it presents a small hollow within called the *fossa ovalis*, indicating the place which the *foramen ovale* occupied in the fœtus. The auricle presents below a large opening which leads to the right ventricle. The internal surface of the auricle presents its *columnæ carneæ*, that is, an infinite number of prolongations, rounded or flat, crossed in every direction, so as to present a sort of *areolar*, or spongy tissue, spread over the internal surface of the auricle, and forming a layer, more or less thick, upon its surface. (77)

In the place where the *vena cava* joins the auricle, there is sometimes a fold observed upon the internal membrane, called the valve of *Eustachius*.

Right ventricle.

The right ventricle has a larger cavity and thicker sides than the auricle; its form is a triangular prism, the base of which corresponds with the auricle and the pulmonary artery, and the top to the point of the heart; all its surface is covered with projections long and rounded, which are also called *fleshy columns:* their disposition is very

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(77) Dr. Duncan, jun., Professor of Materia Medica in the University of Edinburgh, has lately shown, that the cavities of the base are quite independent, but subordinate structures, to the cavities of the apex, which form the proper heart. By boiling for a long time in warm water, the auricles can be separated without the laceration of a single fibre. He has also demonstrated, that the *columnæ carneæ* are formed by the external spiral fibres of the ventricle, collected into bundles, after they have wound their course to the interior through the auriculo-ventricular orifice. The obscure hints of Lower, and another ancient anatomist, had been entirely forgotten, till the Doctor dragged them into notice by his paper, which contains so many interesting observations on a subject which has long been considered as exhausted.

Fleshy column of the right ventricle.

irregular. Like those of the auricle they form a hollow or reticular tissue in the whole length of the ventricle, and particularly towards the point.

The columns of the ventricle being generally larger than those of the auricle, produce a network with broader meshes. Some of them that spring from the surface of the ventricles, terminate by forming one or several tendons, which are attached to the free edge of the *tricuspid* valve, placed at the opening by which the auricle and ventricle communicate. The orifice of the pulmonary artery is beside this, a little to the left.

The sides of the auricle and ventricle are formed of three layers: the one exterior, of a serous nature; the other interior, similar to the internal membrane of the veins; and the middle one of a muscular nature, essentially contractile. This layer is thin in the auricle, but much thicker in the ventricle.

The arrangement of the innumerable fibres of which it is composed is very difficult to unravel. Many estimable authors have made them a particular object of study; but notwithstanding their patience and address, the disposition of these fibres is still very little known: happily there is no necessity to have a perfect idea of them, in order to comprehend the action of the auricle and that of the ventricle.

The heart has arteries, veins, and lymphatic vessels; its nerves come from the great sympathetic, and spread either on the parietes of the arteries, or on the muscular tissue.

Of the Pulmonary Artery.

It arises from the right ventricle and goes to the lungs. At first it forms only one trunk: very soon it is divided into two branches, one of which goes to the *right side* of the lungs, and the other to the left. Each of these branches is divided and subdivided to such a degree as to form an immense multitude of small vessels, the tenuity of which is almost beyond the reach of the senses.

The divisions and subdivisions of the pulmonary artery are remarkable, in forming no communication with each other until they have become excessively minute. The last divisions appear to be a continuation of the radicles of the pulmonary veins.

The pulmonary artery is formed of three tunics: the one exterior, very strong, and of a cellular nature; the other internal, very smooth on its internal surface, and always lubricated by a very thin fluid; and a middle one, with circular fibres, very elastic, that has been long supposed muscular, but which possesses nothing of this character. However, it appears to be fibrinous in its chemical nature: at least, re-agents have much the same effect upon it as on fibrin.

Course of the Venous Blood.

The best informed physiologists avow that the circulation of the venous blood is still very little understood. We shall describe here only its most apparent phenomena, leaving the most delicate questions until we treat of the relation of the flowing of the blood in the veins, with that in the arteries. We will then speak of the cause that determines the entrance of the blood in the venous radicles.

Course of the blood in the veins.

To have a general, but just idea of the course of the blood in the veins, we must consider that the sum of the small veins forms a cavity much larger than that of the larger but less numerous veins, into which they pass; that these bear the same relation to the trunks in which *they* terminate: consequently, the blood which flows in the veins from branches towards the trunks, passes always from a larger to a smaller cavity; now, the following principle of hydro-dynamics may here be perfectly applied:

When a liquid flows in a tube which it fills completely, the quantity of this liquid which traverses the different sections of the tube in a given time ought to be every where the same: consequently, when the tube increases, the velocity diminishes; when the tube diminishes, the velocity increases, in rapidity.

Experience confirms this principle, and its just application to the current of venous blood. If a very small vein is cut, the blood flows from it very slowly; it flows quicker from a larger vein, and it flows with considerable rapidity from an open venous trunk.

Generally, there are several veins to transport the blood that has traversed an organ toward the large trunks. On account of their anastomoses, the compressure or ligature of one or several of these veins does not prevent or diminish the quantity of blood that returns to the heart; it merely acquires a greater rapidity in the veins which remain free.

This happens when a ligature is placed on the arm for the purpose of bleeding. In the ordinary state the blood, which is carried to the fore-arm and the hand, returns to the heart by four deep veins, and at least as many superficial ones; but as soon as the ligature is tightened, the blood passes no longer by the subcutaneous veins, and it traverses with difficulty those which are deeper seated. If one of the veins is then opened at the bend of the arm, it passes out in form of a continued jet, which continues as long as the ligature remains firm, and stops as soon as it is removed.

Except in particular cases, the veins are not much distended by the blood; however, those in which it moves with the greatest rapidity are much more so: the small veins are scarcely distended at all. For a reason very easy to be understood, all the circumstances that accelerate the rapidity of the blood in a vein, produce also an augmentation in the distension of the vessel.

The introduction of blood into the veins taking place in a continued manner, every cause which arrests its course produces distension of the vein, and the stagnation of a greater or less quantity of blood in its cavity, below the obstacle.

Influence of the sides of the veins on the motion of the blood.

The sides of the veins seem to have but a small influence upon the motion of the blood; they easily give way when the quantity augments, and return to their usual form when it diminishes; but their contraction is limited; it is not sufficiently strong to expel the blood completely from the vein, and therefore those of dead bodies always contain some. In living animals I have often seen veins empty without being contracted on that account, and at other times I have observed that the column of liquid did not nearly fill the cavity of the vessel.

A great number of veins, such as those of the bones, of the sinus, of the *dura mater*, of the testicles, of the liver, &c., the sides of which adhere to an inflexible canal, can have evidently no influence upon the motion of the blood that flows in their cavity.

However, it is to the elasticity of the sides of the veins, and not to a contraction similar to that of the muscles, that we must attribute the faculty which they possess of diminishing in size when the column of blood diminishes: this diminution is also much more marked in those that have the thickest sides, such as the superficial veins.

Circumstances which favour the motion of venous blood.

If the veins have themselves very little influence upon the motion of the blood, many other accessary causes exert a very evident effect. Every continued or alternate pressure upon a vein, when strong enough to flatten it, may prevent the passage of the blood; if it is not so strong, it will oppose the dilatation of the vein by the blood, and consequently favour its motion. The constant pressure which the skin of the members exerts upon the veins that are below it, renders the flow of the blood more easy and rapid in these vessels: We cannot doubt this, for all the circumstances that diminish the contractility of the tissue of the skin, are sooner or later followed by a considerable dilatation of the veins, and in certain cases by varix; we know also that mechanical compression, exerted by a proper bandage, reduces the veins again to their ordinary dimensions, and also regulates the motion of the blood within them.

In the abdomen, the veins are subject to the alternate pressure of the diaphragm, and of the abdominal muscles, and this cause is equally favourable to the flow of the venous blood in this part.

The veins of the brain support also a considerable pressure, which must produce the same result.

Whenever the blood runs in the direction of its weight, it flows with greater facility; the contrary takes place when it flows against the direction of its gravity.

Relations of the thickness of the sides of the veins with the causes which retard the motion of the blood.

We must not neglect to notice the relations of these accessory causes with the disposition of the veins. Where they are very marked, the veins present no valves, and their sides are very thin, as is seen in the abdomen, the chest, the cavity of the skull, &c.; where these have less influence, the veins present valves and have thicker sides; lastly, where they are very weak, as in the subcutaneous veins, the valves are numerous, and the sides have a considerable thickness.

If we wish to have an idea comparatively exact of this relation, we have only to examine the internal saphæna vein, the crural and the commencement of the external iliac at the opening of the femoral aponeurosis, intended for the passage of the *vena saphæna:* the difference will be striking in the thickness of the sides.

I lately made this comparison upon the dead body of a criminal that was very muscular: the sides of the *saphæna* were as thick as those of the carotid artery; the crural, and particularly the external iliac veins, were much thinner in their parietes than the former.

Causes which augment the volume of blood contained in veins.

We must take care, however, not to confound amongst the circumstances favourable to the motion of the blood in the veins, causes which act in another manner.

For example, it is generally known that the contraction of the muscles of the fore arm, and the hand during bleeding, accelerate the motion of the blood which passes through the opening of the vein; physiologists say that the contraction of the muscles compresses the deep veins, and expels the blood from them, which then passes into the superficial veins. Were it thus, the acceleration would be only instantaneous, or at least of short duration, whilst it generally continues as long as the contraction. We will see farther on, how this phenomenon ought to be explained.

When the feet are plunged some time in hot water, the subcutaneous veins swell, which is generally attributed to the rarefaction of the blood. I think the true cause is the augmentation of the quantity of blood in the feet, but particularly at the skin, an augmentation which ought naturally to accelerate the motion of the blood in the veins, since they are in a given time traversed by a greater quantity of blood.

Modifications of the motion of venous blood.

After what has preceded, we can easily suppose that the venous blood must be frequently stopt or hindered in its course, either by the veins suffering too strong a pressure in the different positions of the body, or by other bodies pressing upon it, &c.: hence the necessity of the numerous anastomoses that exist not only in the small veins, but amongst the large, and even amongst the largest trunks. By these frequent communications, one or several of the veins being compressed in such a way, that they cannot permit the passage of the blood, this fluid turns and arrives at the heart by other directions:—one of the uses of the azygos vein appears to be to establish an easy communication between the superior and inferior vena cava. I believe, however, that its principal utility consists in being the common termination of most of the intercostal veins.

There is no obscurity in the action of the valves of the veins; they are real valves, which prevent the return of the blood towards the venous radicles, and which do this so much better in proportion as they are large, that is to say, more suitably disposed to stop entirely the cavity of the vein.

The friction of the blood against the sides of the veins, its adhesion to the same sides, and the want of fluidity, must modify the motion of the blood in the veins, and tend to retard it; but in the present state of physiology and hydro-dynamics, it is impossible to assign the precise effect of each of these particular causes.

Modifications of the motion of the venous blood.

We ought to perceive by what has been said upon the motion of the venous blood, that it must undergo great modifications, according to an infinity of circumstances; we shall have occasion to be more convinced of this afterwards when we notice in a general manner the circulation of the blood, without regard to its arterial or venous qualities.

At any rate, the venous blood of every part of the body arrives at the right auricle of the heart by the trunks that we have already named; viz. two very large, the venæ cavæ, and one very small, the coronary vein.

The blood probably flows in each of these veins with different rapidity, what is certain, is, that the three columns of liquid make an effort to pass into the auricle, and that the effort must be considerable.

Absorption by the Veins.

Venous absorption.

The venous radicles (78) not only receive immediately the blood of the last arterial ramifications, but they present another remarkable phenomenon. Every sort of gas or liquid placed in contact with the different parts of the body, except the skin, passes directly into the small veins, and goes to the lungs with the venous blood.

The same takes place for all solid substances susceptible of solution by the blood, or by the secreted fluids. They are very soon introduced into the veins, and carried to the heart and the lungs. This introduction is called *venous absorption.*

Let us study this phenomenon carefully, without allowing ourselves to be influenced by the word *absorption;* it would seem to indicate that the substances which pass into

(78) In a late number of our author's Journal de Physiologie, he appears to have demonstrated, that fluids enter these radicles of the veins by simple transudation. The reader will consult this journal with much advantage.

the veins are drawn into their interior by a power proper to these vessels: this power possibly exists, but it certainly would be impossible at present to demonstrate its existence, and it is equally possible that this introduction takes place in another manner: Therefore, without paying attention to the word *absorption*, we ought, in the phenomenon which it designates, merely to see the *passage* of the different solid or liquid substances in contact with our organs, into the venous radicles, a passage of which the cause and the mechanism are entirely unknown.

Experiments upon venous absorption.

If we wish to have an idea of this property, which is common to all the veins, we have only to introduce a solution of camphor in water, into one of the serous or mucous cavities of the body, or to thrust a small bit of solid camphor into the tissue of an organ: a few moments after, the air which passes out from the lungs has a very distinct smell of camphor. This observation is easily made upon man after the administration of camphorated clysters; after five or six minutes the breath generally presents a very strong odour of camphor.

A similar effect is produced by almost all the odoriferous substances that do not combine with the blood.

In my experiments upon the absorption of veins, I have found that the quickness of absorption is variable according to the different tissues: for example, it is much more rapid in the serous than in the mucous membrane; quicker in the tissues where there are many blood vessels than in those that contain few, &c.

The corrosive quality of the liquids or solids submitted to absorption do not prevent its taking place; it seems, on the contrary, even to be quicker than that of the substances which do not attack the tissues.*

It is the villi of the intestines, formed in part by the origins of the veins, which absorb all the liquids passing through the small intestines, except the chyle; we may easily be convinced of the fact, by introducing into this intestine substances of a strong odour which are susceptible of absorption. From the commencement of absorp-

* Modern Physiologists speak much of the sensibility peculiar to the absorbent orifices—of that fine and unerring tact, by which they distinguish and prefer the useful from the noxious. Our mind, greedy of images, is peculiarly charmed with this ingenious hypothesis, but which is destroyed, the moment it is submitted to experiment.

tion until it is finished, the properties of these substances are discoverable in the blood of the different branches of the vena porta, whilst they are not distinguished in the lymph until long after the absorption has begun. We will see, elsewhere, that they arrive at the thoracic duct, not by the absorption of the chyliferous vessels, but by the communication of the arteries with the lymphatics.

It is well known that all the veins of the digestive organs unite in one trunk, which is divided and subdivided in the tissue of the liver. This disposition is worthy of remark.

Particular use of the vena porta.

On account of the considerable extent of the mucous surface, with which the drinks or other liquids are in contact, and of the rapidity of their absorption by the mesaräic veins, a considerable quantity of liquid, foreign to the economy, traverses the abdominal venous system in a given time, and changes the composition of the blood. If this liquid arrived at the lungs in this manner, and proceeded from thence to all the organs, very serious inconveniences might arise, as will be seen by the following experiments.

About fifteen grains of bile, rapidly injected into the crural vein, generally causes the death of an animal in a few moments. The same thing happens by a certain quantity of atmospheric air being suddenly introduced into the same vein. The injection being made in the same manner into one of the branches of the vena porta, would have no apparent inconvenience. Why this difference of results? Can the passage of liquids foreign to the economy, through the innumerable small vessels of the liver, have the effect of mixing them more intimately with the blood, and of spreading them through a greater quantity of this fluid, in such a way that its chemical nature is somewhat changed by them? This is so much the more probable, as the same quantity of bile or air injected very slowly into the crural vein produces no sensible accidents.

The passage of the veins arising from the digestive organs across the liver may then be necessary, in order to mix intimately with the blood the matters absorbed by the intestinal canal. Whether this effect takes place or not, it is not doubtful that medicines absorbed in the stomach and the intestines do not pass immediately across the liver, and it appears to me that they have not a sufficient influence upon this organ to deserve the attention of physicians.*

I have just now said that the skin is an exception to that general law, that the veins absorb in every part of the body. This proposition deserves a particular examination.

Venous absorption of the skin.

When the skin is deprived of the epidermis, and the blood vessels that cover the external surface of the chorion are laid bare, absorption takes place there as every where else. After the application of a blister, if the surface from which the epidermis is removed is covered with a substance, the effects of which are easy to be remarked upon the animal economy, sometimes a few minutes are sufficient for them to be seen. Caustics applied to ulcerated surfaces have often produced death.

In order that inoculation of the small pox, or matter of vaccination may take place, it is necessary to place the substance under the epidermis, and consequently to put it in contact with the subjacent blood vessels.

It is very different when the skin is covered with epidermis. There is no sensible absorption, if the substances in contact with it are not of a nature to attack its chemical composition, or to excite an irritation of the corresponding blood vessels.

I know that this result is contrary to the generally received ideas. For example, it is supposed that the body, being plunged in a bath, absorbs a part of the liquid by which it is surrounded; upon this idea rest the use of nourishing baths of milk, of broth, &c. M. Seguin, in a work published lately, has, by a series of exact experiments, put it quite out of doubt, that the skin does not absorb the water amongst which it is placed. To ascertain if it were the same with other liquids, M. Seguin made essays upon persons affected with venereal diseases. He caused them to plunge their feet and legs into baths, composed of sixteen pounds of water, and three grains of sublimate; each bath continued an hour or two, and was re-

Experiments upon the absorption of the skin.

* It would be curious to know why, of all the vessels of the liver, the branches of the vena porta are the only ones which, by the disposition of their external membrane, are able to contract when the blood which passes through them diminishes in quantity. Perhaps that disposition is favourable to the progress of the blood, which here passes from a small to a larger space, directly contrary to what happens in the other vessels.

peated twice a-day. Thirteen sick persons, who submitted to this treatment during eight days, presented no appearance of absorption; a fourteenth presented evident marks of it from the third bath, but he had scabby excoriations on the legs: two others, that were in the same situation, presented similar phenomena. In general, absorption did not take place except where the epidermis was not entirely whole; however, at the temperature of eighteen degrees,(79) there was sometimes sublimate absorbed, but never water.

Amongst the experiments of M. Seguin, there is one which appears to throw great light upon the absorbent faculty of the skin.

Experiment.

After having weighed separately a dram each containing 72 French, 59.1 Troy grains, of sweet mercury, a dram of gamboge, a dram of scammony, a dram of *sal alembroth*, or muriate of mercury and ammonia, and a dram of tartar emetic, M. Seguin made a sick person lie upon his back, washed carefully the skin of the abdomen, and applied with precaution upon places separated from each other, the five substances mentioned above; he covered each with a watch-glass, and kept them all in their places with a linen bandage. The heat of the chamber was kept at fifteen degrees;(79) M. Seguin did not quit the patient, in order to prevent him from stirring: the experiment continued ten hours and a quarter. The glasses were then taken away, and the substances removed with great care; they were afterwards weighed. The sweet mercury was reduced to 71⅓ grains; the scammony weighed 72¾ grains; the gamboge a little more that 71 grains; the *sal alembroth* was reduced to 62 grains (a great many pimples were produced on the place where it was applied;) the tartar emetic weighed 67 grains. It is plain that in this experiment those substances that are most irritating, and most disposed to combine with the epidermis, were partly absorbed, whilst the others were not sensibly so. But what does not happen by simple application takes place when the skin is submitted to friction with certain substances. We cannot doubt that mercury, alcohol, opium, camphor, the emetics, the purgatives, &c., pass by this means into the venous system. These different medicines appear to traverse the epidermis, perhaps by pass-

Absorption of the skin.

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(79) 18°R. : 73°F., and 15°R. : 66°F.

ing through the pores, or the openings by which the hairs or the insensible perspiration pass out to the surface.

Thus, to sum up what relates to absorption by the skin, we see that this membrane is not different from the other surfaces of the body, except in being covered by the epidermis. As long as this layer remains entire, and does not permit the substances put in contact with the skin to pass, there is no absorption; but as soon as it is worn through, or otherwise penetrated, absorption takes place the same as it does every where else.

I am well aware that many persons will be astonished at my having no hesitation in attributing the absorbent faculty to the veins, whilst the general opinion is, that every sort of absorption takes place by the lymphatic vessels; but after the facts noticed at the article concerning the *absorption of the lymph*, and some others that I shall add, I cannot possibly think otherwise. But the opinion that I sustain is not new; Ruysch, Boerhaave, Meckel, Swammerdam, professed it; and it was sustained by Haller, though he was not ignorant of the anatomical labours of J. Hunter.(80)

Experiment upon venous absorption.

M. Delille and myself separated from the body the thigh of a dog, that we had first laid asleep with opium, to prevent the pain inseparable from such an experiment;(81) we left untouched only the crural artery and the crural vein, which preserved the communication between the thigh and the trunk. These two vessels were dissected with the greatest care, that is to say, they were isolated the extent of 15.75 inches; their cellular tunic was taken away, to prevent the concealment of the lymphatic ves-

(80) Haller did not think J. Hunter's experiments conclusive. His words are—"I esteem highly this gentleman's experiments, in which candour appears combined with industry. But we possess so numerous a train of arguments to the contrary, that I cannot recede from the opinion of my great preceptor Boerhaave."—*El. Phys. VII.* 69.

(81) The beautiful experiment here related by our author might easily be repeated so as to avoid a serious objection. It is urged that the *thrusting* or *forcing* the poison into the paw of the animal could not be effected without penetrating many small veins, which might thus receive of a poison, so fatal as the *upas*, a sufficient quantity by injection, or inoculation, to produce death; in short, that the experiment, by the mode of inserting the poison, reduces itself to a mere venous injection. To avoid this, the cuticle simply ought to be removed, or, at most, the true skin, and the experimentalist to content himself with simply applying the poison to the undefended surface.

sels. Two grains of a very subtle poison (the upas tieuté) were then thrust into the foot: the effects of this poison were as rapid and as intense as if the thigh had not been separated from the body; they began before the fourth minute, and the animal was dead before the tenth.

It might be objected, that notwithstanding all the precautions taken, the sides of the artery and the crural vein still contained lymphatics, and that these vessels afforded a passage to the poison. To remove this difficulty, I repeated the preceding experiment upon another dog, with this difference, that I introduced into the crural artery the tube of a small quill, upon which I bound this vessel by two ligatures; the artery was afterwards divided circularly between the two ligatures, and the same thing was done with the crural vein; there was then no communication between the thigh and the body, except by the arterial blood that arrived at the thigh, and the venous blood returning to the trunk. The poison being then introduced into the foot produced the ordinary effects, that is, death in about four minutes.

Another experiment.

This experiment removes all doubt of the passage of the poison from the foot to the trunk through the crural vein. To render the phenomenon still more clear, if this vein is pressed between the fingers at the instant the poison begins to take effect, these effects very soon cease: they appear again as soon as the vein is left at liberty, and cease as soon as it is compressed anew. They may thus be graduated at will.

Experiments upon venous absorption.

We will add to these facts, which appear decisive, some interesting observations made by Flandrin.

The matters which the large and small intestine of the horse generally contain, are mixed with a great quantity of liquid, which becomes less considerable as we advance towards the rectum: it is then absorbed in proportion as it flows along the intestinal canal. Now, Flandrin having collected the liquid contained in the chyliferous vessels, found no odour in it similar to that of the liquid of the intestine: on the contrary, the venous blood of the small intestine had an odour sensibly herbaceous; that of the cæcum had a sharp taste, and a slightly urinous savour; that of the colon had the same characters, but more strongly marked. The blood of the other parts of the body presented no similarity to this.

Half a pound of assafœtida, dissolved in the same quantity of honey, was given to a horse; the animal was fed as usual, and killed sixteen hours afterwards. The odour of the assafœtida was distinguished in the veins of the stomach, of the small intestine, and the cæcum; it was not noticed in the arterial blood, nor in the lymph.

At the article treating of the *Lymphatic Vessels*, I noticed the experiments made by J. Hunter, to prove that these vessels are the exclusive agents of absorption. This author has also made experiments to prove that these vessels do not absorb; but these are not much more satisfactory nor more exact than those given above.

"I took," says J. Hunter, "a portion of the intestine of a sheep, after having cut open the parietes of the abdomen; I tied it at the two extremities, and filled it with hot water: the blood that returned by the vein of this part, did not appear more *diluted* or *lighter coloured* than that of the other veins; I then tied the artery and all its communications, and I examined the state of the vein. It did not swell, its blood did not become more watery; thus it gave no indication of the presence of water in its cavity. The veins therefore do not absorb."*

How many objections present themselves when we wish for precision in experiments! How could J. Hunter judge from simple appearance that in the first instant, the water was not absorbed and did not mix with the blood of the vein? Then, how could it be believed by this author, who is in other respects so estimable, that the vein could continue its action when the artery was tied? He ought to have first determined the effects of the ligature on an artery upon the motion of the blood in its corresponding vein, and this is what he did not do.

In another experiment the same physiologist injected warm milk into a portion of the intestine; a few moments afterwards he opened the mesenteric vein, collected the blood which flowed from it, and because he did not find any trace of milk, he concluded that there was no absorption of this liquid by the vein. But in the time of J. Hunter there was no means of ascertaining the existence of a small quantity of milk in a considerable quantity of blood; even at the present time, when animal chemistry is far advanced, this obstacle can scarcely be surmounted.

* Med. Comm. V.

These two experiments can have no effect upon the doctrine of venous absorption. The others, which are six in number, so far from being conclusive, are, on the contrary, more defective.

Lastly, were it necessary to deduce from reasoning new proofs in favour of the absorbent property of veins, I would notice that, in many parts of the body where the most exact anatomy has never been able to discover any other than blood vessels, and no lymphatics, such as the eye, the brain, the placenta, &c., absorption takes place as rapidly as elsewhere; I would add, that all the invertebral animals, which have blood, have no lymphatics, and yet absorption takes place. The thoracic canal is indeed much too small to give a sufficiently rapid passage to the matters absorbed in every part of the body, and particularly to the drinks.* These phenomena are all perfectly well understood, as soon as the absorption of veins is admitted.

Therefore, facts, experiments, and reasoning, concur in favour of venous absorption.†

Passage of the venous blood through the right cavities of the Heart.

Action of the right cavities of the heart.

If the heart of a living animal is laid bare, it is easily seen that the right auricle and ventricle open and shut alternately. These motions are so combined, that the contraction of the auricle happens at the same time with the dilatation of the ventricle, and *vice versa*, the contraction of the ventricle takes place at the same instant as the dilatation of the auricle. Neither the one nor the other of these cavities can dilate without being filled immediately with blood, and when they contract they necessarily expel a part of that which they contained. But such is the play of the *tricuspid*, and *sigmoid* valves, that the blood is forced to pass successively from the auricle into the ventricle, and from thence into the pulmonary artery.

* Some persons drink two or three gallons of mineral waters in a few hours, and reject them almost at the same instant by urine.

† To sum up what we have said upon the organs of absorption generally considered, it may be stated,—1st, That it is certain the chyliferous or lacteal vessels absorb the chyle; 2d, that it is doubtful whether they absorb any thing else; 3d, that it is *not demonstrated* that the lymphatic vessels are endowed with the absorbing faculty; and that it *is* proved that the veins enjoy that power.

Action of the right auricle.

Let us enter into the details of this curious mechanism. I have said that the blood of the three veins that are in the right auricle makes a considerable effort to penetrate into it. If it is contracted, this effort has no effect; but, as soon as it dilates, the blood enters its cavity, fills it completely, and even distends the sides a little; it would immediately enter the ventricle, if it did not contract itself at this instant. The blood, then, confines itself to filling up exactly the cavity of the auricle; but this very soon contracts, compresses the blood, which escapes into the place where there is least compression; now it has only two issues: 1st, by the vena cava; 2dly, by the opening which conducts into the ventricle. The columns of blood which are coming to the auricle present a certain resistance to its passage into the cavæ or coronary veins. On the contrary, it finds every facility to enter the ventricle, since the latter dilates itself with force, tends to produce a vacuum, and consequently draws on the blood instead of repulsing it.

Reflux of blood in the veins.

However, all the blood that passes out of the auricle does not enter the ventricle; it has been long observed that, at each contraction of the auricle, a certain quantity of blood flows back into the superior and inferior venæ cavæ; the undulation produced by this cause is sometimes felt as far as the external iliac veins, and into the jugulars; it has a sensible influence, as we will see, upon the flowing of the blood in several organs, and particularly in the brain.

The quantity of blood which flows back in this manner, varies according to the facility with which this liquid enters the ventricle. If, at the instant of its dilatation, the ventricle still contains much blood which has not passed into the pulmonary artery, it can only receive a small quantity of that of the auricle, and then the reflux will be of greater extent.

Venous pulse.

This happens when the flowing of the blood in the pulmonary artery is retarded, either by obstacles in the lungs, or by the want of sufficient force in the ventricle. This reflux, of which we speak, is the cause of the beating which is seen in the veins of certain sick persons, and which bears the name of *venous pulse*. Nothing similar can take place in the coronary vein, for its opening is furnished with a valve, which shuts on the instant of the contraction of the auricle.

The instant in which the auricle ceases to contract, the ventricle enters into contraction, the blood it contains is strongly pressed, and tends to escape in every direction: it would return so much more easily into the auricle, that, as we have already frequently said, it dilates just at this instant; but the tricuspid valve which shuts the *auriculo-ventricular* opening prevents this reflux. Being raised by the liquid introduced below it, and which tends to pass into the auricle, it gives way until it has become perpendicular to the axis of the ventricle; its three divisions then shut almost completely the opening, and as the tendons of the *columnæ carneæ* do not permit them to go farther, the valve resists the effort of the blood, and thus prevents it from passing into the auricle. Action of the right ventricle.

It is not the same with the blood which during the dilatation of the ventricle corresponded to the auricular surface of the valve; it is evident that in the motion of the ventricle it is carried forward into the auricle, where it mixes with that which comes from the *venæ cavæ* and coronary veins.

Not being able to overcome the resistance of the tricuspid valve, the blood of the ventricle has no other issue than the pulmonary artery, into which it enters by raising the three sigmoid valves that supported the column of blood contained in the artery during the dilatation of the ventricle.

I have explained the most apparent and best known phenomena of the passage of the venous blood through the right cavities of the heart; there are several others that appear to deserve attention.

A. We should form an erroneous idea were we to suppose that, in the contraction of the ventricle or the auricle, these cavities empty themselves completely of the blood they contain: in observing the heart of a living animal at the instant of contraction, the auricle or ventricle is seen to diminish sensibly in size; but evidently at the instant when the contraction stops, there is still a considerable quantity of blood in the auricle or in the ventricle. Remarks upon the action of the right cavities of the heart.

Only a part, then, of the blood of the auricle passes into the ventricle when it contracts. The same thing happens with the blood of the ventricle, of which only a portion passes into the pulmonary artery when the ventricle enters into contraction; these two cavities are therefore always full of blood. How could the proportion of blood that is displaced, and that which remains, be determined? These must vary according to the force with which the ventricle or the auricle contract, the facility of the passage of the blood into the pulmonary artery, the quantity of blood contained in the auricle or ventricle, the effort of the three columns of blood that open into the auricle, &c.

Remarks upon the action of the right cavities.

B. As soon as the venous blood arrives in the heart, it is continually agitated, pressed, and beaten by the motions of this organ; sometimes it flows back into the *venæ cavæ*, or enters the auricle; sometimes it passes quickly into the ventricle, and quits it to pass again into the auricle, and immediately returns into the ventricle; sometimes it penetrates into the pulmonary artery, then re-enters the ventricle, and suffers a violent agitation at each removal.*

The blood, being so much agitated and pressed during the time it remains in the cavities of the heart, and in the pulmonary artery, it must undergo a more intimate mixture of its constituent parts. The chyle and the lymph that the two subclavian veins receive, must be equally distributed in the blood of the two *venæ cavæ*. These two sorts of blood must also be completely mixed and lost in each other.

I am inclined to think, with Boerhaave, that the fleshy columns of the right cavities, besides their uses in the contraction of these cavities, must have a considerable part in this collision, this mixture of the different elements of the blood. Indeed, the blood that is in the auricle and ventricle not only fills the central cavity, but also all the small cells formed by the columns; therefore, at each contraction, it is driven in part from the cells, and replaced at each dilatation by new blood. Being so divided into a great number of small portions, which fill the cells and re-unite when they are expelled from them, the blood is so agitated, that its different elements undergo a mixture very intimate, and very necessary in this liquid, the parts of which have such a tendency to separate. The chyle, the lymph, the drinks, which are carried to the heart by the veins, and which have not yet been sufficiently mixed with the blood, must, by the same means, undergo this mixture in traversing these cells.

If we desire to witness, in this respect, the influence of

* To have an idea of the great energy of the heart, one touch of it in the living animal will suffice.

the right side of the heart, we have only to inject a quantity of air rapidly into the jugular vein of a dog, and a few moments after examine the heart, we will see the air agitated in the auricle, and a great quantity of fine froth formed in the ventricle. I have often observed these phenomena in living animals; I have lately proved them upon a horse, the heart of which was previously laid bare by an incision in the lateral parts of the thorax, and the division of one of the ribs.

Passage of Venous Blood through the Pulmonary Artery.

Notwithstanding the numerous labours of physiologists on the motion of the blood in the arteries, much still remains to be done on this subject.

Here we can be guided only by observation and experience; the explanations must be very limited, for *Hydrodynamics*, the science that ought to furnish them, has scarcely any existence in all that relates to the motion of fluids in flexible canals.*

Action of the pulmonary artery

I shall not adopt the plan followed by authors in my description of the motion of the blood in the pulmonary artery; I prefer noticing first the motion of the blood in this artery at the instant of relaxation of the right ventricle, and afterwards observing what happens when this ventricle contracts and presses the blood into the artery. This plan appears to have the advantage of setting, in the clearest light, a phenomenon, the importance of which, I think, has not been sufficiently appreciated.

Contraction of the pulmonary artery.

Suppose the artery full of blood, and left to itself, the liquid will be pressed in the whole extent of the vessel by the sides which tend to contract upon the cavity; the blood being thus pressed will endeavour to escape in every

* I cannot refrain from quoting here the appropriate language of D'Alembert: "The mechanism of the human body, the velocity of the blood, its action on the vessels, refuse to submit to theory: We know neither the action of the nerves, nor the elasticity of the vessels, nor their variable capacity, nor the tenacity of the blood, nor its different degrees of heat. Even were each of these circumstances known, the great multitude of elements which must enter into calculation, would probably conduct us to impracticable equations: it is one of the most complex cases of a problem, of which the simplest case would be extremely difficult to resolve. When the effects of nature," adds this illustrious geometer, "are too complicated to be submitted to our calculations, experience is the only way which remains to us."

direction: now it has only two ways to pass, by the cardiac orifice, and by the numerous small vessels that terminate the artery in the tissue of the lungs.

The orifice of the pulmonary artery in the heart being very large, the blood would easily pass into the ventricle, if there were not a particular apparatus at this orifice intended to prevent this: I mean the three sigmoid valves. Being pressed against the sides of the artery, at the instant that the ventricle sends a wave of blood that way, these folds become perpendicular to its axis, as soon as the blood tends to flow back into the ventricle, they place themselves so as to shut up the cavity of this vessel completely.

Use of the sigmoid valves.

On account of the bag-like form of the sigmoid valves, they are swelled by the blood that enters into their cavity, and their margin tends to assume a circular figure. Now, three circular portions, placed upon each other, necessarily leave a space between them.

When the valves, therefore, of the pulmonary artery are lowered by the blood, there ought to remain an opening by which this liquid may flow back into the ventricle.

If each valve were alone, it would, undoubtedly, take a semicircular form; but there are three of them: being pressed by the blood they lie all close together: and as they cannot extend as far as their fibres permit them, they press upon each other, on account of the small space in which they are contained, and which does not permit their extending themselves. The valves then assume the figure of three triangles, whose summit is in the centre of the artery, and the sides are in *juxtaposition*, so as completely to intercept the cavity of the artery. Perhaps the *knots*, or *buttons*, which are upon the summit of some of the triangles, are intended to shut more perfectly the centre of the artery.*

In order to view this folding of the valves, melted grease or wax ought to be injected very slowly into the pulmonary artery, and directed towards the ventricle; the injected matter having reached the valves, fills them, and folds them against each other, and the orifice of the vessel is so perfectly shut, that not a drop of the injection passes into the ventricle. When the grease, or wax, are solidi-

* Senac, Traite de Cœur, &c.

fied by cooling, the manner in which the valves shut the opening of the artery may then be examined.

Finding no passage into the ventricle, the blood will pass into the radicles of the pulmonary veins, with which the small arteries that terminate the pulmonary artery form a continuation, and this passage will continue as long as the sides of the artery press the contained blood with sufficient force; and, except in the trunk and the principal branches, this effect continues until the whole of the blood is expelled.

We might suppose the smallness of the vessels that terminate the pulmonary artery an obstacle to the flowing of the blood: that might be if they were not numerous, or if the capacity of the whole were less, or even equal to that of the trunk; but as they are innumerable, and their capacity is much greater than that of the trunk, there is no difficulty in the motion. It is true that the distension or subsidence of the lungs, renders this passage more or less easy, as will be seen farther on. Action of the pulmonary artery

In order that this flowing may take place with facility, the force of contraction of the different divisions of the artery ought to be every where in relation to their size; if, on the contrary, that of the small were greater than that of the large, as soon as the first had expelled the blood by which they were filled, they would not be sufficiently distended by the blood coming from the second, and the flowing of the blood would be retarded: now, what takes place is quite the contrary of this supposition. If the pulmonary artery of a living animal were tied immediately above the heart, almost all the blood contained in the artery at the instant of the ligature, would pass quickly into the pulmonary veins, and arrive at the heart.

This is what happens when the blood contained in the pulmonary artery is exposed to the single action of this vessel; but in the common state at each contraction of the right ventricle, a certain quantity of blood is thrown with force into the artery; the valves are immediately raised; the artery and almost all its divisions are so much more distended, in proportion as the heart is more forcibly contracted, and as the quantity of blood injected into the artery is greater. The ventricle dilates immediately after its contraction, and at this instant the sides of the artery contract also; the sigmoid valves descend and shut the pulmonary artery, until they are raised by a new contraction of the ventricle.

Such is the second cause of the motion of the blood in the artery that goes towards the lungs; we see it is intermittent; let us endeavour to appreciate its effects: for which purpose let us consider the most apparent phenomena of the flow of the blood in the pulmonary artery.

Phenomena of the flow of blood in the pulmonary artery

I have just said that in the instant the ventricle injects the blood into the artery, the trunk, and all the divisions of a certain size undergo an evident dilatation. This phenomenon is called the *pulsation* of the artery. The pulsation is very sensible near the heart; it becomes feeble in proportion to its distance from it; when the artery, by being divided, has become very small, it ceases.

Another phenomenon, which is only the consequence of the preceding, is observed when the artery is opened.

If it be near the heart, and in a place where the beating is sensible, the blood spouts out by jerks; if the opening be made far from the heart, and in a small division, the jet is continued and uniform; lastly, if one of the very small vessels that terminate the artery be opened, the blood flows, but without forming any jet: it flows uniformly in a sheet.

We see at first in these phenomena a new application of the principle of hydro-dynamics, as already mentioned, with regard to the influence of the size of the tube upon the liquid that flows in it: the greater the tube is, the rapidity is the less. This capacity of the vessel increasing according as it advances towards the lungs, the quickness of the blood necessarily diminishes.

Flow of the blood in the pulmonary artery.

With regard to the pulsation of the artery, and the jet of blood that escapes from it when it is open, we see plainly that these two effects depend on the contraction of the right ventricle, and the introduction of a certain quantity of blood into the artery, which takes place by this means. Why do these two effects become weaker in proportion to the distance? and why do they cease entirely in the last divisions of the artery? I think it is not impossible to give a satisfactory mechanical reason for it. Let us suppose a cylindrical canal of any length, with elastic sides, and full of liquid; if all at once a certain quantity of new liquid is introduced, the pressure will be equally distributed over all the points of the sides which will be equally distended.

Explanation of the cessation of pulsation in the small arteries.

Let us now suppose that the canal is longitudinally divided into two parts, the united sections of which form a surface equal to that of the section of the canal; the distension produced by the rapid introduction of a certain quantity of liquid will be less felt in the two divisions than in the canal: for the whole circumference of the two canals being greater than that of the single one, it will give more resistance; and if we suppose that these first divisions are divided and subdivided *ad infinitum*, as the sum of the circumferences of the small canals will be much greater than that of the single canal, the same cause that produces a sensible distension in the canal and its principal divisions, will not produce any that can be felt in the last divisions, on account of the more considerable resistance of the sides.* The phenomenon will be still more remarkable if the capacity of the divisions, in place of being equal, be greater than that of the canal. This last supposition is realized in the pulmonary artery, the capacity of which augments in proportion as it is divided and subdivided; it is consequently evident that the effects of the introduction of the quantity of blood at every contraction of the right ventricle, must diminish by the distance, and cease entirely in the last divisions of the vessel.

What ought not to be omitted is, that the contraction of the right ventricle is the cause that constantly keeps the elasticity of the sides of the artery in play; that is, which maintains them in a state of distension to such a degree, that, by virtue of their elasticity, they continually tend to contract and expel the blood. According to this we see that, of the two causes that move the blood in the pulmonary artery, only one exists in reality; this is the contraction of the ventricle, that of the artery being only the effects of the distension it undergoes when a certain quantity of blood has entered its cavity by the pressure of the ventricle.

Some authors have supposed that this closing of the pulmonary artery presents something analogous to the

* To comprehend this, it must be recollected, that circles are to each other as the squares of their diameters. Thus, in the proposed division into two others, if each circumference became only half the primitive one, the areas of each of the secondary canals would only be a fourth of the area of the primitive canal; and their two areas united would only equal the half of the primitive area. That they may equal, the united circumferences of the two divisions must exceed the circumference of the primitive canal.

contraction of the muscles; but, if it be either pricked by the point of an instrument, or irritated by caustic, or if it be submitted to a galvanic current, still no motion takes place similar to that of the muscular fibres. This contraction, then, ought to be considered as the effect of the elasticity of the sides of the vessel.

Utility of the elasticity of the sides of the arteries.

To show the importance of the elasticity of the sides of the artery, let us suppose it to become an inflexible canal, with its ordinary form and dimensions; the flow of the blood would be instantly changed; in place of traversing the lungs in a continued manner, it would no longer pass into the pulmonary veins, except in the instant when pressed by the ventricle; this last must also be supposed to send always as much blood as will keep the artery quite full; were it otherwise, the ventricle might be several times contracted before the blood would pass into the lungs. In place of that, let us see what really happens: let the ventricle cease for some instants to send blood into the artery, the flow of the blood into the lungs will nevertheless continue, for the artery will contract according as the blood flows, and the flow of the blood would not stop entirely until the artery contained no more: this stoppage of the blood cannot take place during life. The passage of the blood through the lungs is necessarily continued, and nearly of equal rapidity, whatever be the quantity of blood sent by the ventricle into the pulmonary artery at each contraction.

Quantity of blood that passes out of the ventricle at each contraction.

The quantity of blood that enters into the pulmonary artery, at each contraction of the ventricle, has been repeatedly endeavoured to be determined; generally the capacity of the ventricle has been taken as the measure, on the supposition that all the blood which is in it passes into the artery at the instant of contraction; the quantity has been supposed considerable; but, what has been said above shows how inexact this estimate is, and as it is impossible to know how much enters and how much remains, these calculations evidently cannot be considered as true.

What is most necessary to be known is the mechanism by which the blood passes from the ventricle into the artery, and that of its flowing in this vessel; though the quantity of blood which passes in a given time were known exactly, it would not be of great utility.

Of the Respiration, or transformation of the Venous Blood into Arterial Blood.

While flowing through the small vessels that terminate the artery, and that give commencement to the pulmonary veins, the venous blood changes its nature by the effect of the contact of the air; it acquires the qualities of arterial blood: it is this change in the properties of the blood which essentially constitutes respiration.

Some authors of estimation have another idea; several define it the entrance and passage out of the air from the lungs, but this double motion may take place without respiration. Others think that it consists in the passage of the blood through the lungs; but this passage frequently takes place without any respiration.

To study this function with success, it is necessary to have an exact knowledge of the structure of the lungs, and precise ideas of the chemical and physical properties of the air; we must know by what mechanism the air enters and passes out of the chest. After we have determined each of these points, we will describe the phenomenon of the transformation of venous into arterial blood.

Of the Lungs.

Of the Lungs.

The lungs are two spongy and vascular organs, of a considerable size, situated in the lateral parts of the chest. Their parenchyma is divided and subdivided into lobes and lobules, the forms and dimensions of which it is difficult to determine.

We learn by the careful examination of a pulmonary lobule, that it is formed of a spongy tissue, the *areolæ* of which are so small that a strong lens is necessary to observe them distinctly; these *areolæ* all communicate with each other, and they are surrounded by a thin layer of cellular tissue which separates them from the adjoining lobules.

Structure of the Pulmonary Lobules.

Into each lobule enters one of the divisions of the bronchia and one of the pulmonary artery; this last is distributed in the body of the lobule in a manner that is not well known; it seems to be transformed into numerous radicles of the pulmonary veins. I would very readily believe that these numerous small vessels, by which the artery terminates and the pulmonary veins begin, by crossing and joining in different manners, form the *areolæ* of the tissue of the lobules.* The small bronchial division that ends in the lobule, does not enter into the interior of it, but breaks off as soon as it has arrived at the parenchyma.

This last circumstance appears remarkable; because, since the bronchia does not penetrate into the spongy tissue of the lungs, it is not probable that the surface of the cells with which the air is in contact is covered by the mucous membrane. The most minute anatomy cannot prove its existence in this place.

Structure of the Lungs. A part of the nerve of the eighth pair, and some filaments of the sympathetic, are expended on the lungs, but it is not known how they are distributed; the surface of the organ is covered by the pleura, a serous membrane, similar to the *peritonæum* in its structure and functions.

Round the *bronchia*, and near the place where they enter into the tissue of the lungs, a certain number of lymphatic glands exist, the colour of which is almost black, and to which the small number of lymphatic vessels which spring from the surface and from the interior of the pulmonary tissue are directed.

With regard to the lungs, we receive from the art of delicate injections some information that we ought not to neglect.

If we inject mercury, or even coloured water into the pulmonary artery, the injected matter passes immediately into the pulmonary veins, but at the same time a part enters the *bronchia* and goes out by the *trachea*. If the matter be injected into a pulmonary vein, it passes partly into the artery and partly into the bronchia. Lastly, if it be introduced into the trachea, it very soon penetrates into the artery, into the pulmonary veins, and even into the *bronchial* artery and vein.

The lungs fill up a great part of the cavity of the chest, and enlarge and contract with it; and as they communicate with the external air by the trachea and the larynx, every time that the chest enlarges it is distended by the air, which is again expelled when the chest resumes its former dimensions. We must then necessarily stop to examine this cavity.

Of the thorax. The breast, or the thorax, is of the form of a *conoid*, the summit of which is above and the base below; behind,

* This structure is somewhat more evident in the lungs of reptiles.

the chest is formed by the dorsal *vertebra;* before, by the *sternum;* and laterally, by the *ribs;* these last bones are twelve in number in each side: the ribs are divided into *vertebro-sternal,* and *vertebral.* There are seven of the first, and five of the second. The vertebro-sternal, or the true ribs, are above; they articulate behind with the vertebra, like the vertebrals, and before, with the sternum, by means of a prolongation called the *cartilage of the ribs.*

The apparent form and dimensions of the breast are determined by the length, disposition, and motions of the ribs upon the vertebra.

The same muscle that, as we have seen, forms the superior parietes of the abdomen, forms also the inferior parietes of the thorax; it is attached by its circumference to the outline of the base of the breast; but its centre rises into the pectoral cavity, and when relaxed it forms a vault, the middle of which is on a level with the inferior extremity of the sternum: so that the cavity of the thorax is divided into two portions, the superior or *pectoral,* and the inferior or *abdominal.* In the first only are lodged the pectoral organs, such as the lungs, the heart, &c. The second contains the liver, the spleen, the stomach, &c.

Numerous muscles are attached to the bones that form the frame of the thorax; some of these muscles are intended to render the ribs less oblique upon the vertebral column, or to enlarge the capacity of the breast; others lower the ribs, render them more oblique upon the vertebral, and thus diminish the capacity of the thorax.

It is necessary to take notice of the mechanism by which the breast is enlarged or diminished, many phenomena of respiration being intimately connected with its variations of capacity.

The chest is capable of being dilated vertically, transversely, forward and backward, that is, in the direction of its principal diameters.

Enlargement of the thorax by contraction of the diaphragm.

The principal and almost the only agent of the vertical dilatation is the diaphragm, which, in contracting, tends to lose its vaulted form, and to become a plane, a motion which cannot take place without the pectoral portion of the thorax increasing, and the abdominal portion diminishing.

The sides of this muscle, which are fleshy, and correspond with the lungs, descend farther than the centre, which, being aponeurotic, can make no effort by itself, and which is besides retained by its union with the *sternum* and the *pericardium*.

In most cases this lowering of the diaphragm is sufficient for the dilatation of the breast; but it often happens that the sternum and the ribs, in changing the position between them and the vertebral column, produce a sensible augmentation in the pectoral cavity.

Mechanism of the motion of the ribs.

As soon as the physical disposition of the parts is well known, nothing is more easy to conceive than the mechanism of this motion; it has, nevertheless, been the object of keen discussions between authors of consideration, who have given to the question an importance which perhaps it did not deserve.

If such disputes could lead to the truth, the time spent in them by learned men might be less regretted; but this result rarely takes place; at least it has not happened with regard to the mechanism of the dilatation of the thorax. Haller, after a great number of reasonings, and apparently perfect experiments, succeeded in making his ideas predominate, and yet they are any thing but satisfactory.

I will explain myself on this point with all the freedom that such respectable authority demands.

Ideas of Haller upon the motions of the ribs.

His explanation of the dilatation of the thorax, generally adopted at present, rests upon a foundation which I think false: he lays down as a fact that the first rib is nearly immoveable, and that the thorax cannot make any total movement either up or down. It is difficult to conceive how so able an observer as Haller could advance and maintain such an idea; for it is sufficient to examine the motions of respiration in *one's self*, to prove that the sternum and the first rib rise in inspiration, and descend in expiration. The examination of the thorax in the dead body gives the same result; the sternum has only to be drawn upwards, it yields, and all the sternal ribs, comprehending the first, move upon the vertebral column, and the thorax sensibly enlarges.

After having established that the first rib is almost immoveable, he says that the second presents a mobility five or six times greater; that the third is still greater; and that the mobility goes on increasing to the very last.

In noticing only the true ribs, which alone are of importance here, I believe that observation is quite contrary to what Haller has advanced, that is, that the first rib is more moveable than the second, the second than the third, and so on to the seventh.*

Relation of the mobility of the ribs with their length.

But in judging soundly of the degree of mobility of the ribs, we must not observe the motion of their extremity alone; because, as they are of unequal length, a slight motion in the articulation when the rib is long, will appear greater at the extremity; in the same manner, a considerable motion in the articulation of a short rib when examined at its extremity, would appear small. On the contrary, it is necessary to consider the motion of the ribs all at the same length, and it will be evidently seen that the mobility decreases from the first to the seventh; this last is almost immoveable. (82)

The anatomical disposition of the posterior articulations is the cause of this difference of mobility.

Reasons of the first rib being moveable.

The first rib has only one articular facet at its head, and articulates with only one vertebra; it has no internal ligament, nor no *costo-transversal* ligament. The posterior ligament of the articulation is horizontal with the transverse *apophysis*, and can prevent neither the elevation nor the descent of the rib.

* Hall. El. Physiol. iii. 39.

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(82) The motion of the ribs, as described here by our author, is so singular, and founded on such slight reasoning, that it would be improper to allow it to pass without remark. The *quantity of motion* of any body is measured by the space it passes through in a given time; consequently in the ribs, by their *relative ascent or descent*, in a given time. The most moveable point of each rib lies near its middle, as may be ascertained by a mere inspection of a thin man or animal while breathing, and this, therefore, is the point at which the relative motion of one rib ought to be, and generally is, compared with that of another. Whoever keeps this in view, and takes the trouble to inspect the inspiration of a lean person, or still better, the inspiration of a person whose opposite lung is hepatised, will easily satisfy himself that the statements delivered in the text as Haller's, but which were known 1500 years ago, are still correct; that the first rib is the most immoveable of the upper ribs; and that their mobility increases as we descend from it. I have a suspicion, however, that the three lower ribs exhibit less motion than those above them, decreasing in motion as they descend. Our author indeed is right, but not original, in stating that the first rib has some mobility: but he seems to conclude too much from this, and to confound mobility with absolute motion, although obviously two very different things. As to his notions respecting the inadequacy of the intercostal muscles to inspiration, they are refuted by Galen's famous experiment (Admin. Anat. VIII. c. 3. 45.) in which he suspended respiration by dividing the intercostal nerves, and which was afterwards many times repeated by Haller.—*Memoire sur la Respiration, in Opusc. Minor.*

None of these favourable dispositions exist in the other true ribs; they have two articular facets at their heads, and articulate with two vertebræ.

There is an internal ligament in the articulation which permits no slipping; a *costo-transversary* ligament fixed to the superior transverse *apophysis* prevents the descent of the rib; a posterior ligament, directed downwards, is seen behind the articulation of the tuberosity, and prevents the elevation of the rib. At any rate, little shades of difference in the disposition of these different ligaments, permit the different degrees of mobility that we have mentioned.

Besides, the least mobility being in the largest ribs, this makes up the difference, and they can perform movements as extensive as the first, though less moveable; by the same cause they may possibly present a more extensive motion.

This compensation is indispensable; for the true ribs, their cartilages, the sternum, cannot move except together; and the motion of one always occasions that of the whole; it then follows that if the inferior ribs were more moveable, they could not produce a motion more extensive than that of which they are susceptible, and the solidity of the thorax would be diminished without any advantage for the mobility.

In most subjects, and often in the most advanced age, the sternum is composed of two pieces articulated by moveable *symphysis* to the level of the cartilage of the second rib. This disposition, permitting the superior extremity of the inferior piece to go a little forward, contributes to the enlargement of the breast in such a manner as I believe has not hitherto been noticed.

Muscles that raise the ribs and the sternum.

But what muscles raise the sternum and the ribs, and therefore dilate the chest? If we can believe Haller, the intercostals are the principal agents of this elevation. He says that the first intercostals find a fixed point upon the first rib, which is immoveable, and raises the second rib; and the other intercostals all in succession take their fixed point upon the superior rib and raise the inferior.

We have just now seen that the first rib is far from being immoveable; then the explanation of Haller is by this rendered null, and I do not think that the external or internal intercostals are capable, whatever has been said of them, of producing the elevation of the ribs. I think the muscles intended for this use are those that, having mediately or immediately one extremity fixed upon the vertebral column, the head, or the other superior members, can act by the other, either directly or indirectly, upon the thorax, in such a manner as to raise it.

Amongst these muscles, I would notice the posterior and anterior *scaleni*, the supracostals, the muscles of the neck, that are attached to the *sternum*, &c. I would add a muscle to which this use has not hitherto been attributed, which is the diaphragm. In fact, this muscle is attached, by its circumference, to the inferior extremity of the sternum, to the seventh true rib, and to all the false ones; when it contracts it presses down the *viscera;* but for that the sternum and the ribs must present a sufficient resistance to the effort that it makes to draw them upwards; now, the resistance must be imperfect, since all the parts are moveable; therefore, every time the diaphragm contracts, it must always raise the thorax more or less. In general, the extent of the elevation will be in a direct ratio to the resistance of the abdominal viscera, and to the mobility of the ribs.

In the general elevation of the thorax, its form necessarily changes, as well as the relations of the bones of which it is composed; the cartilages of the ribs seem particularly intended to assist these changes: as soon as they are ossified, and consequently lose their elasticity, the breast becomes immoveable.

Mechanism of the dilatation of the cartilage.

Whilst the sternum is carried upwards, its inferior extremity is directed a little forward; it thus undergoes a slight swinging motion; the ribs becomes less oblique upon the vertebral column; they remove a little from each other, and their inferior edge is directed outward by a small tension of the cartilage. All these phenomena are not very apparent except in the superior ribs.

A general enlargement of the thorax takes place by its elevation, as well from front to back, as transversely, and upwards.

Three degrees of inspiration.

This enlargement is called *inspiration;* it presents three degrees: 1st, ordinary *inspiration*, which takes place by the depression of the diaphragm, and an almost insensible elevation of the thorax; 2dly, the *great* inspiration, in which there is an evident elevation of the thorax, and, at the same time, a depression of the diaphragm; 3dly, *forced* inspiration, in which the dimensions of the thorax are augmented in every direction, as far as the physical disposition of this cavity will permit.

Expiration succeeds to the dilatation of the thorax, that is, the return of the thorax to its ordinary position and dimensions.

The mechanism of this motion is the reverse of what we have just described. It is produced by the elasticity of the cartilages, and by the ligaments of the ribs, which have a tendency to resume their former shape, by the relaxation of the muscles that had raised the thorax, and by the contraction of a great number of muscles, so disposed that they lower and contract the chest. Amongst these muscles, which are very numerous and strong, the large muscles of the abdomen ought to be distinguished, the *serratus posticus*, the *latissimus dorsi*, the *sacro-lumbalis*, &c.

Three degrees of expiration.

The contraction of the thorax, or expiration, presents also three degrees: 1st, *ordinary expiration;* 2d, *great expiration;* 3d, *forced expiration.*

In ordinary expiration, the relaxation of the diaphragm, pressed upwards by the abdominal viscera, which are themselves urged by the anterior muscles of this cavity, produces the diminution of the vertical diameter; vehement expiration is produced by the relaxation of the inspiring muscles, and a slight contraction of those of expiration, which permits the ribs to assume their ordinary relations with the vertebral column. But the contraction of the chest may go still farther. If the abdominal and other expiratory muscles contract forcibly, a greater repression of the diaphragm takes place, the ribs descend lower, the base of the *conoid* shrinks, and there is, consequently, a greater diminution of the capacity of the thorax. This is called forced expiration.

OF THE AIR.

On all sides, to the height of about 15 or 16 leagues, the earth is surrounded with a rare and transparent fluid named *air*, the whole mass of which forms the atmosphere.

Air is an elastic fluid, which possesses the property of exerting pressure upon the bodies it surrounds, and upon the sides of the vessels that contain it. This property supposes, in the particles of air, a continual tendency to repulse each other. Physical properties of air.

Another property of the air is *compressibility;* that is, its volume changes with the pressure which it supports. We learn, by experience, that the same mass of air submitted successively to different pressures, occupies spaces or volumes which are in an inverse ratio to the pressures, so that the pressure being double, treble, quadruple, the volume is reduced to the half, the third, the fourth.

In the atmosphere, the pressure which any mass supports proceeds from the weight of the layers that are upon it; the weight diminishing according to the elevation, the air must be more and more dilated, or, in other terms, its density must diminish according as the elevation augments. At the surface of the earth, the pressure of the air is the result of the whole weight of the atmosphere. This pressure is capable of sustaining a column of mercury of the height of 29½ or 30 English inches: the instrument employed to determine this measure is called a *barometer.*

Different physical circumstances cause a variation of the atmospheric pressure; for example, it is less upon the tops of mountains than in the valleys; greater when the air is charged with humidity than when it is dry. These variations are exactly determined by the barometer.

The air expands by heat like all other bodies; its volume augments $\frac{1}{480}$ by an increase of one degree of Fahrenheit's thermometer.

The air has weight; this is ascertained by weighing a vessel full of air, and then weighing the same vessel after the air has been taken out by the air pump.

Thus it has been found that at the temperature of 32° F., when the barometer is at 29½ inches, a *litre* of air, that is, 61 cubic inches of air weigh 20 grains; the same volume of water would weigh a kilo-gramme, or 15,444 grains. Water is, then, 770 times heavier than air.

The air is more or less charged with humidity. This humidity proceeds from the continual evaporation of the waters that cover the surface of the earth. In fact, we find, by experience, that water forms vapours at all temperatures, but they are more abundant in proportion as the temperature is high. Also the air contains only a certain quantity of vapour for each temperature; when it is saturated the humidity is extreme. The more it approaches this state the greater is the humidity. This is shown by hydrometers. Lastly, when by the effect of cold or any other cause the air contains more vapour than is proper for it at that temperature, the excess of that vapour gathers first in the form of mists and clouds, and then falls in the state of rain and snow, &c.

The vapour of water being lighter than air, and causing it to expand when it is mixed with it; from this it results that humid air is lighter than air which is dry.

Air, notwithstanding its thinness and transparency, refracts, intercepts, and reflects the light. In a small mass it sends too few rays for the colour to produce any sensible effect upon our eyes; in a great mass this colour is very visibly blue. Distant objects also receive a blue tint from the interposition of the air. The air has a great influence in chemical phenomena; it was long considered as an element, but its composition, which was suspected by John Rey in the seventeenth century, was clearly established by Lavoisier. (83)

Chemical composition of air.

The air is composed of two gases that are very different in their properties.

1st, Oxygen; this gas is a little heavier than air, in the proportion of 11 to 10, and it combines with all the simple bodies; it is an element of water, of vegetable and animal matters, and of almost all known bodies; it is essential for combustion and respiration. 2dly, Azote; this gas is a little lighter than air; it is an element of ammonia and of animal substances; it extinguishes bodies in combustion.

The proportions of oxygen and azote that enter into the composition of air are determined by instruments called *eudiometers*.

In those instruments, the combination of oxygen with some combustible body, such as hydrogen or phosphorus, is produced, and by the result of this combination the quantity of oxygen contained in the air is known. It has been thus found that 100 parts in weight of air contain 21

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(83) It is generally believed that Mayow was prior to J. Rey in this particular. Certainly Priestley preceded Lavoisier in the discovery of oxygen.

parts of oxygen and 79 of azote. These proportions are the same in every place and at all heights, and have not sensibly changed for these fifteen years since they were positively established by chemistry.

Besides oxygen and azote, the air contains a variable quantity of the vapour of water, as we have already observed, and a *small quantity* of carbonic acid, the proportion of which has not yet been positively fixed.

The air is decomposed by almost all combustible bodies, at a temperature which is peculiar to each. In this decomposition they combine with the oxygen and set the azote at liberty.

Inspiration and Expiration.

Entrance of the air into the lungs.

If we call to mind the disposition of the pulmonary lobules, the extensibility of their tissue, their communication with the external air by means of the bronchia, of the trachea, and of the larynx, we will easily conceive that every time the breast dilates, the air immediately enters the pulmonary tissue, in a quantity proportionate to the degree of dilatation. When the breast contracts, a part of the air that it contains is expelled, and passes out by the glottis. (84)

In order to arrive at the glottis in inspiration, or to go outwards in expiration, the air sometimes traverses the nasal canal and sometimes the mouth: the position of the velum of the palate in these two cases deserves to be described. When the air traverses the nasal canals and the pharynx to enter or to pass out of the larynx, the velum

(84) Dr. Carson, of Liverpool, has lately maintained, that the lungs act as a kind of pump, in attracting the blood from the venous system into the heart. During expiration, less blood than usual passes through the lungs: hence, by expanding the lungs in inspiration, more blood than otherwise would, passes along the pulmonary artery to the pulmonary mass—hence, more is sent into the ventricle by the auricle, and more into the auricle by the veins, and so on. Now, so far the comparison to a pump is just and natural: but the grand supposed point of resemblance is utterly untenable: there is no process in the human body that at all resembles the removal of atmospherical pressure. Let the reader compare the only real human case of it, the operation of sucking, with that attributed to the lungs, and the difference will become evident. Air rushes into the inspiring lung, because the ascent of the thorax, by affording space, has allowed the contained air to expand itself to a degree of tenuity which can no longer balance the atmosphere.

of the palate is vertical, and placed with its anterior surface against the posterior part of the base of the tongue, so that the mouth has no communication with the pharynx. When the air traverses the mouth in inspiration or expiration, the velum of the palate is horizontal, its posterior edge is embraced by the concave surface of the pharynx, and all communication is cut off between the inferior parts of the pharynx and the superior part of this canal, as well as with the nasal canals. Thence the necessity of making the sick breathe by the mouth, if it is necessary to examine the tonsils or the pharynx.

These two ways for the air to arrive at the glottis were necessary, for they assist each other: thus when the mouth is full of food the respiration takes place by the nose; it takes place by the mouth when the nasal canals are obstructed by mucus, by a slight swelling of the *pituitary*, or any other cause. The glottis opens in the instant of inspiration, and, on the contrary, it shuts in the expiration.

The time that the air stops in the lungs.

It appears that in a given time the number of inspirations made by one person are very different from those of another. Hales thinks there are twenty in the space of a minute. A man upon whom Menzies made experiments respired only fourteen times in a minute. Sir H. Davy informs us that he respires in the same period 26 or 27 times; Dr. Thomson says that he respires generally 19 times; I only respire 15 times. Taking 20 times in a minute for the mean, this will give 28,800 inspirations in twenty-four hours. But this number probably varies according to many circumstances, such as the state of sleep, motion, distension of the stomach by food, the capacity of the chest, moral affections, &c. What quantity of air enters the chest at each inspiration, what quantity goes out at each expiration? How much generally remains?

Number of inspirations in 24 hours.

According to Menzies, the mean quantity of air that enters the lungs at each inspiration, is 40 cubic inches.—Goodwin thinks that the quantity remaining after a complete expiration is 109 cubic inches; Menzies affirms that this quantity is greater, and that it amounts to 179 cubic inches.

According to Davy, after a forced expiration, his lungs contained 41 cubic inches.

After a natural expiration - - - - - - - - -	118
After a natural inspiration - - - - - - - - -	135
After a forced inspiration - - - - - - - - -	254

By a forced expiration, after a forced inspiration, there passed out of the lungs - - - - - - -	190
After a natural inspiration - - - - - - - - -	78.5
After a natural expiration - - - - - - - - -	67.5 c. i.

Quantity of air usually contained in the lungs.

Dr. Thomson thinks that we should not be far from the truth in supposing that the ordinary quantity of air contained in the lungs is 280, and that there enter or go out at each inspiration or expiration 40 inches. Thus, supposing 20 inspirations in a minute, the quantity of air that would enter and pass out in this time would be 800 inches; which makes 48,000 in the hour, and in 24 hours 1,152,000 cubic inches. A great number of experiments have been made by chemists to determine if the volume of air diminishes while it remains in the lungs. In considering the latest experiments, it appears, that in most cases there is no diminution, that is, a volume of expired air is exactly the same as one of inspired air. When this diminution takes place it appears to be only accidental.

Physical changes of the air inspired.

By successively traversing the mouth or the nasal cavities, the pharynx, the larynx, the trachea, and the bronchia, the inspired air becomes of a similar temperature with the body. It most generally becomes heated, and consequently rarified, so that the same quantity in weight of air occupies a much greater space in the lungs than it occupied before it entered them. Besides this change of volume, the inspired air is charged with the vapour that it carries away from the mucous membranes of the air-passages, and in this state always, hot and humid, it arrives in the pulmonary lobules; also this portion of air of which we treat mixes with that which the lungs contained before.

But expiration soon succeeds to inspiration: an interval, only of a few seconds, passes in general between them; the air contained in the lungs, pressed by the powers of expiration, escapes by the expiratory canal in a contrary direction to that of the inspired air.

Partial renewal of the air contained in the lungs.

We must here remark that the portion of air expired is not exactly that which was inspired immediately before, but a portion of the mass which the lungs contained after inspiration; and if the volume of air that the lungs usually contains is compared with that which is inspired and expired at each motion of respiration, we will be inclined to believe that inspiration and expiration are intended to renew in part the considerable mass of air contained by the lungs.

This renewal will be so much more considerable as the quantity of air expired is greater, and as the following inspiration is more complete.

Physical and Chemical changes that the Air undergoes in the Lungs.

The air, in its passage from the lungs, has a temperature nearly the same as that of the body; there escapes with it from the breast a great quantity of vapour called *pulmonary transpiration*; besides, its chemical composition is different from that of the inspired air. The proportion of azote is much the same, but that of oxygen and carbonic acid is quite different.

Chemical changes of the air of the lungs.

In place of 0.21 of oxygen and a trace of carbonic acid which the atmospheric air presents, the expired air gives 0.18 or 0.19 of oxygen and 0.3 to 0.4 of carbonic acid: generally the quantity of carbonic acid exactly represents the quantity of oxygen which has disappeared; nevertheless the last experiments of MM. Gay Lussac and Davy give a small excess of acid, that is, there is a little more acid formed than the oxygen absorbed.

Quantity of oxygen consumed.

In order to determine the quantity of oxygen consumed by an adult in 24 hours, we have only to know the quantity of air respired in this time. According to Lavoisier, and H. Davy, 32 cubic inches are consumed in a minute, which gives for 24 hours 46,037 cubic inches.

It is not difficult to appreciate the quantity of carbonic acid that passes out of the lungs in the same time, since it nearly represents the volume of oxygen that disappears. Thomson values it at 40,000 cubic inches, though he says it is probably a little less: now this quantity of carbonic acid represents nearly 12 ounces avoirdupois of carbon.

Some chemists say that a small quantity of azote disappears during respiration, others think, on the contrary, that its quantity is sensibly augmented; but there is nothing positive in this respect.

Quantity of carbonic acid formed.

We are informed of the degree of alteration that the air undergoes in our lungs by a feeling which inclines us to renew it: though this is scarcely sensible in ordinary respiration, because we always continue it, it nevertheless becomes very painful if we do not satisfy it quickly; carried to this degree it is accompanied with anxiety and fear, an instinctive warning of the importance of respiration.

Whilst the air contained in the lungs is thus modified in its physical and chemical properties, the venous blood traverses the ramifications of the pulmonary artery, of which the tissue of the lobules of the lungs is partly formed; it passes into the radicles of the pulmonary veins, and very soon into these veins themselves; but in passing from the one to the other, it changes its nature from venous to arterial blood.

Let us examine the phenomena of this transformation.

Change of Venous into Arterial Blood.

At the instant in which the venous blood traverses the small vessels of the pulmonary lobules, it assumes a scarlet colour; its odour becomes stronger, and its taste more distinct, its temperature rises about a degree; a part of its serum disappears in the form of vapour in the tissue of the lobules, and mixes with the air. Its tendency to coagulate augments considerably, which is expressed by saying that its *plasticity* becomes stronger, its specific gravity diminishes, as well as its capacity for caloric: The venous blood having acquired these characters now becomes arterial blood.

In order to render the difference between the venous and arterial blood more distinct, we give the following table of them.

Principal differences of Venous and Arterial Blood.

	Venous Blood.	Arterial Blood.
Colour	Brown red	Vermilion red.
Odour	Weak	Strong.
Temperature	101.75°. F.	Near 104°. F.
Capacity for caloric	852*	839.
Specific gravity	1051†	1049.
Coagulation	Less rapid	More rapid.
Serum	More abundant	Less abundant.

I described above the changes that the air undergoes in the lungs, and I have just explained those that happen to the venous blood in traversing these organs; let us now see what connection can be established between those two orders of phenomena. Theory of respiration

* Water being 1000. † Water being 1000.

The colour of the blood evidently depends upon its mediate contact with oxygen; because, if there is any other gas in the lungs, or even if the air is not suitably renewed, the change of colour does not take place. It is shown anew as soon as the oxygen is permitted to pass into the pulmonary lobules.

We can easily see the colouring of the blood even in the dead body. Often before death the venous blood accumulates in the vessels of the lungs; the bronchial lobules being deprived of air, it preserves the venous properties long after death. Atmospheric air injected into the trachea, so as to distend the tissue of the lungs, immediately changes the *brown red* colour of the accumulated blood into *vermilion red.*

Colouring of the blood.

The same phenomenon takes place whenever the venous blood is in contact with oxygen or atmospheric air.

Blood being drawn from a vein and exposed to the air reddens on the surface; immediate contact is not necessary. The same blood contained in a bladder, and plunged into oxygen gas, becomes scarlet in all the points of its surface. Thus, the very thin vascular parietes that are in the lungs, placed between the atmospheric air and the blood, ought not to be considered as any obstacle to its colouring.

But, how does oxygen gas produce this change of colour in venous blood? (85) Chemists are not agreed on this point. Some think that the gas combines immediately with the blood; others imagine that it carries away part of its carbon; and there are others who almost believe that these two effects take place at the same time: but none of these explanations give any reason for the change of colours.

Several chemists have attributed to iron the colouring of the blood, but this opinion is now rejected as doubtful; however, it is so much the more probable, that, if this metal be separated from the colouring part of the blood,

(85) There seems to be no good reason why oxygen should not enter the system by *transhalation,* through the membrane of the lungs, since all acknowledge that oil of turpentine, prussic acid, opium, and many poisons find a passage in this way. Nay, we have seen above, that M. Magendie has proved that all venous absorption is effected by transudation. Hippocrates's maxim, that "*the whole man is inspiratory and expiratory,*" turns out to be more general in its application than was once imagined.

this substance, which has a *wine-red colour*, loses the property of becoming scarlet by oxygen gas.

Pulmonary transpiration.

We more easily understand the loss of serum by the blood in respiration: this probably depends upon a certain quantity of serum escaping from the last divisions of the pulmonary artery, and evaporating in the air what the lobules contain. This vapour passes out afterwards with the air under the name of *pulmonary transpiration*.

It must not be understood, however, that all the vapour that passes out in expiration proceeds from the blood of the pulmonary artery; I will show, a little farther on, that a considerable part of this vapour is formed by the arterial blood which is spread in the mucous membrane of the air-passages. Lavoisier, in his first researches upon respiration, believed that there might be a combustion of hydrogen in the lungs, by which a certain quantity of water would be produced. A part of the pulmonary transpiration would have been formed by this water; but this idea is not now admitted, and this transpiration, as we have already noticed, is considered as the result of the passage into the bronchial vesicles of a part of the liquid that flows in the pulmonary artery. Anatomy directs us to this phenomenon. Water injected into the pulmonary artery passes under the form of innumerable small drops almost imperceptible into the air-cells, and mixes with the air contained in them.

Experiments upon pulmonary transpiration.

The quantity of pulmonary transpiration is augmented at will in living animals, by injecting into the venous system distilled water, at a temperature nearly equal to that of the body; this is proved by the following experiment: take a dog of small size; inject at different times a considerable quantity of water, the animal will be at first in a state of real plethora, his vessels will be so full that he will be scarcely able to move; but in a few moments the motions of respiration will sensibly accelerate, and an abundance of liquid will flow from every point of his mouth, the source of which is plainly the transpiration of the lungs considerably increased.

It is not only the watery part of the blood that escapes by pulmonary transpiration. I have shown, by particular experiments, that many substances introduced into the veins by absorption, or direct injection, very soon pass out by the lungs.

Weak alcohol, a solution of camphor, ether, or other substances introduced into the cavity of the peritoneum, or elsewhere, are soon absorbed by the veins; transported to the lungs, they pass into the bronchial vesicles, and we discover them by their odour in the expired air.

The same thing happens with phosphorus; its odour is not only sensible in the expired air, but its presence is easy to be proved in a still more positive manner.

Inject into the crural vein of a dog, half an ounce of oil in which phosphorus has been dissolved: this injection will scarcely have taken place when a thick white vapour will pass from the nose of the animal, which is nothing else but phosphorous acid.

Nearly the same thing happens with the gases, according to the interesting experiments of Dr. Nysten, for after having been injected into the veins they pass out with the expired air.

Attempts have been made to determine the quantity of vapour that escapes from the lungs of an adult in twenty-four hours.

Quantity of pulmonary transpiration.

The last, which are due to Thomson, give about 19 ounces; Lavoisier and Seguin formerly estimated it above 20.4 ounces: it is probably very variable, according to an infinity of circumstances.

Formation of carbonic acid.

Philosophers are not agreed about the manner in which the carbonic acid is formed which is contained in the expired air. Some think that it existed already formed in the venous blood, and that it is exhaled at the instant of its passage through the lungs; others suppose that it is the result of the direct combustion of the carbon of the blood by oxygen: neither of these opinions is sufficiently proved; perhaps the two effects take place together. For the same cause that we do not understand the manner in which the carbonic acid is formed, we are ignorant of the part which the oxygen acts in respiration. It is said by some to be employed in burning the carbon of the venous blood; others imagine that it passes into the pulmonary veins, whilst others think that it does both.

Action of oxygen.

New researches are necessary for all this part of animal chemistry.

So long as we have no principles more fixed upon the formation of carbonic acid, and the disappearance of oxygen in the lungs, it will be difficult to account for the elevation of temperature that the blood undergoes in traversing these organs.

However, as the oxygen very probably combines with the carbon of the blood, and as every formation of this sort is accompanied with a considerable disengagement of caloric, it is also probable that this is the source of the greater heat of the arterial blood.

Even supposing that the oxgen is absorbed, and passes directly into the pulmonary veins, and that it afterwards combines directly with the blood, we might still conceive the elevation of the temperature of the blood; for every combination of oxygen with a combustible body is accompanied with a disengagement of heat. Elevation of the temperature of the blood in the lungs.

The slight diminution of the specific gravity and the capacity for caloric probably depend upon the loss of water which takes place at the surface of the pulmonary vesicles. With regard to the other properties that the venous blood acquires in traversing the lungs, such as the plasticity, odour, the stronger taste; in order to have satisfactory ideas on this point, it would be necessary to have a very exact comparative analysis of venous and arterial blood, that their differences might be perfectly known; but Physiology still requires this assistance from chemistry.

Respiration of the Gases which are not Atmospheric Air.

We have not been satisfied with studying the effects of the respiration of atmospheric air. We have also wished to determine the efforts of the respiration of the other gases. Animals have been plunged into each of them, men have respired them either voluntarily or involuntarily, and it has been found that atmospheric air alone is fit for respiration; animals are destroyed with more or less rapidity by all the other gases; even oxygen, when pure, is destructive of life; and its mixture with azote, in different proportions from that of the air, always kills the animals that breathe it, sooner or later. Action of the non-respirable gases.

By making these different experiments, the gases have been divided into two classes with regard to their respiratory qualities; 1st, the non-respirable gases; 2dly, the deleterious gases.

The first, to which belong azote, the protoxide of azote, hydrogen, &c., only kill animals because their action cannot replace that of oxygen; one of these gases, the pro- Gases which are not deleterious.

toxide of azote, produces singular effects, which ought, perhaps, to make it belong to the second class.

Sir H. Davy was the first who dared to study its effects upon himself: after having expired the air of his lungs, he respired nearly 8.4 pints of the protoxide of azote. The first feelings that he experienced were those of giddiness; but in half a minute, continuing to respire, these effects diminished by degrees, and they were replaced by feeling similar to a gentle pressure upon all the muscles, accompanied by agreeable tremblings, particularly in the chest and the extremities. The surrounding objects appeared dazzling, and his hearing became more delicate; towards the last respirations the agitation increased, his muscular force augmented, and he acquired an irresistible propensity to motion. These effects ceased as soon as Davy left off the respiration of the gas, and in ten minutes he became as he was before.

However, these effects are not constantly the same. MM. Vauquelin and Thenard did not experience all the phenomena described by Davy, but other phenomena analogous to them.

Deleterious gases.

The deleterious gases are those that not only cannot support respiration, but very soon kill men or animals that breathe them pure, or mixed in certain proportions with atmospheric air. All the acid gases are of this number, ammoniacal gas, sulphuretted hydrogen, arseniated hydrogen, the deutoxide of azote, &c.

Influence of the Nerves of the eighth pair upon Respiration.

The nerves of the eighth pair being the only cerebral nerves that send filaments into the tissue of the lungs, it must have struck physiologists to cut them in order to examine the effects that would result from it. This easy experiment has frequently been made by the ancients, and most modern physiologists have repeated it.

Influence of the nerves of the eighth pair upon respiration.

Every animal that has the above mentioned nerves cut, perishes more or less quickly; sometimes death happens immediately after the section. Life never continues beyond the third or fourth day. Death has been attributed by authors to the cessation of the motions of the heart, to the cessation of digestion, the inflammation of the lungs, &c.

We are highly indebted upon this subject to the recent labours of MM. Dupuytren, Dumas, Blainville, Provençal, and Legallois. I will give a general summary of their researches.

The section of the nerves of the eighth pair at the neck, as high as the thyroid gland, or even lower, has an influence, 1st, upon the larynx; 2dly, upon the lungs. These two sorts of effects ought to be distinguished.

In treating of the voice, we said that the section of the recurrent nerves immediately produces aphony; the same phenomenon takes place by the section of the eighth pair; this may be easily conceived since the recurrents are only divisions of these nerves. But, besides the destruction of the voice, the section of the nerves of the eighth pair frequently causes such a closing of the edges of the glottis, that the air can no longer penetrate into the larynx, and death very soon happens, as in all those cases in which an animal cannot renew the air of its lungs.

In ordinary cases the closing is not sufficiently perfect to prevent the entrance of the air into the larynx, to keep up the respiration; but the glottis having lost its proper motions, the entrance into, and passage of the air from the chest are always more or less difficult.

Influence of the nerves of the eighth pair upon the larynx.

At the period when these observations were made, it was almost impossible to explain the reason of these different phenomena; but since I explained the manner in which the recurrents and *laryngeal nerves* are distributed to the muscles of the larynx, there is no longer any difficulty. The dilating muscles of the glottis are paralysed by the section of the eighth pair at the lower part of the neck; this opening no longer widens in the instant of respiration, whilst the constrictors, that receive their nerves from the superior *laryngeals*, preserve all their action, and shut the glottis more or less completely.

Influence of the nerves of the eighth pair upon the lungs.

When the section of the eighth pair does not cause such a closing of the glottis that death immediately happens, other phenomena are developed, and death arrives sometimes only at the end of three or four days.

The respiration is at first incommoded, the motions of respiration are more extended, more contracted, and the animal appears to pay particular attention to them; the locomotive motions are less frequent, and they evidently fatigue; sometimes the animal remains perfectly still: however, the formation of the arterial blood is not prevented at first; but very soon, the second day for example, the difficulty of respiration increases, the efforts of inspiration become greater and greater. The arterial blood has not then the vermilion tint which is peculiar to it; it is a little deeper, its temperature lowers; lastly, all the symptoms increase, respiration continues only with the assistance of the whole of the inspiratory powers; the arterial blood is of a dull red, and nearly like the blood of the veins; the arteries contain very little; the cold becomes evident, and the animal soon dies. On opening the chest, the bronchial cells, the bronchia, and often the trachea itself, are found filled with a foamy liquid, which is sometimes bloody; the tissue of the lungs is choaked and voluminous; the divisions, and even the trunk of the pulmonary artery are strongly distended by blood, which is of a deep colour, and almost black: considerable effusions of serosity, and even of blood, take place in the parenchyma of the lungs. On the other hand, we learn, by experiments, that in proportion as this series of accidents takes place, the animals consume less and less of oxygen, and that less and less of carbonic acid is formed.

Influence of the nerves of the eighth pair upon the respiration.

It has been reasonably concluded, that, in this case, animals perish, because the respiration can no longer continue, the lungs being so changed that the inspired air can no longer reach the bronchial lobules. I think that there ought to be added to this cause, the difficulty of the passage of the blood from the artery into the pulmonary veins, a difficulty which, I think, is the cause of the distension of the venous system after death, and of the small quantity of blood that the arterial system contains a short time after it takes place.

The section of only one nerve of the eighth pair producing these effects only upon one part of the lungs, and life continuing by the action of only one part of this organ, death does not ensue. I have seen animals live in this manner several months.

Of Artificial Respiration.

Artificial respiration.

The principal object of the motions of the thorax is to draw the air into the lungs, and afterwards to expel it from these organs. As often as these motions stop, the air of the lungs not being renewed, respiration is discontinued, and death soon takes place. But the want of action of the thorax may be supplied for some time, by introducing air artificially into the lungs. Both ancient and modern anatomists have frequently practised this. The air has been introduced by turns by a bladder, a bellows, &c. At present, a syringe is used, pierced with a small hole in the side. The extremity of the body of the syringe is first introduced into the trachea, and fixed by a ligature; the piston is then drawn, in order to fill the syringe with air; the finger is applied to the small hole, to prevent the air going out; the piston is now thrust in, and the air of the syringe passes into the lungs; the piston is then withdrawn, and the syringe is filled with the air of the lungs. The finger that is placed upon the hole is then removed, and the piston pressed in to drive out the air which was used in respiration; it is then withdrawn in order to fill the instrument with pure air; the hole is then stopped, &c.

By repeating these motions suitably, an animal is kept alive whose thorax has become immoveable, either because the spinal marrow has been cut behind the occipital, or because the head has been entirely cut off; but it replaces, very imperfectly, the natural respiration, and cannot be continued beyond a few hours. The lungs are generally gorged with blood, or torn by the air: this fluid is introduced into the pulmonary veins, and flows into the cellular tissue, so as to prevent the dilatation of the lobules.

COURSE OF THE ARTERIAL BLOOD.

The end of this function is to transport the arterial blood from the lungs to all the parts of the body.

Of the Arterial Blood.

After what we have said of the arterial blood, at the article *Respiration*, there remains little more to be added here upon this liquid. I will only notice, that our learned Professor Vauquelin has lately found in this fluid a considerable quantity of a yellow-coloured fat oil, of a sweet savour, and a soft consistence, and which consequently has, at least in appearance, some analogy with grease. (86)

(86) Dr. Traill, of Liverpool, in the Edinburgh Medical and Surgical Journal (April, 1823), has lately added further confirmation to this circumstance, which ought to be better known, by several observations made by himself.

Globules of the blood.

When, by the aid of a strong lens, or a microscope, we observe the transparent parts of cold-blooded animals, we see in the blood vessels an immense multitude of small, rounded molecules, which swim in the serum, and roll upon each other, whilst they flow through the arteries and the veins.

Similar observations have never been made upon the hot-blooded animals; the membranes and sides of the vessels being opaque. But as, in separating a drop of blood in water, rounded particles are often seen with the microscope, the existence of globules has been admitted for the blood of animals, and consequently for that of man.

Authors have related marvellous things of those globules. According to *Leuwenhoeck,* a thousand millions of those globules are not larger than a grain of sand. Haller, in speaking of cold-blooded animals, for he never could see those of hot-blooded animals, says, that they are to an inch as one inch is to five thousand. Some will have them of the same form and diameter in all animals: others, on the contrary, assert, that they have a particular form and size for each animal; some declare that they are spherical and solid, others that they are flattened, and pierced with a small hole in the centre; lastly, many believe that a globule is a species of small bladder, which contains a certain number of smaller globules.

Globules of blood.

I believe that many errors of imagination, and optical illusions, have slid into these different opinions. I have made a great number of microscopic experiments, in order to satisfy myself in this respect; I have never seen in the blood of man diluted in water, any thing but particles of colouring matter, generally rounded, of different sizes, which, according as they are placed exactly or not in the focus of the microscope, appear sometimes spherical, sometimes flat, and, at other times, of the figure of a disc, pierced in the centre: All these appearances can be produced at pleasure, by varying the position of the particles relatively to the instrument.

I also believe, that bubbles of air have often been described and drawn for globules of blood; at least, nothing has more resemblance to certain figures of Hewson, than very small bubbles of air that are produced by slightly agitating the liquid submitted to the microscope.

Apparatus of the Course of the Arterial Blood.

It is composed, 1st, of pulmonary veins; 2dly, of the left cavities of the heart; 3dly, of the arteries.

Pulmonary Veins.

Pulmonary Veins.

They have their origin, like the veins properly so called, in the tissue of the lungs; that is, they form at first an infinite number of radicles, which appear to be the continuation of the pulmonary artery. These radicles unite to form thicker roots, which become still thicker. Lastly, they all terminate in four vessels, which open, after a short passage, into the left auricle. The pulmonary veins are different from the other veins, in their not anastomosing after they have acquired a certain thickness: a similar disposition has been seen in the divisions of the artery which is distributed to the lungs.

The pulmonary veins have no valves, and their structure is similar to that of the other veins; their middle membrane is, however, a little thicker, and it appears to possess more elasticity.

Left Cavities of the Heart.

Left Ventricle and Auricle.

The form and size of the left auricle are not much different from the right; except in the appendage called *proper auricle*, its surface is smooth, and presents no fleshy column. It communicates by an oval opening with the left ventricle, which is distinguished from the right by the greater thickness of its sides, the number, the volume, and disposition of its fleshy columns: the opening by which the auricle and ventricle communicate is provided with a valve called *mitral*, very similar to the *tricuspid*. The ventricle gives origin to the aorta, the orifice of which presents three valves similar to the sigmoid valves of the pulmonary artery.

Of the Arteries.

Of the Aorta and its divisions.

The *aorta* is to the left ventricle what the pulmonary artery is to the right ventricle, but it is different from it in many important respects; its capacity and extent are much more considerable; almost all its divisions are considered as arteries, and have particular names; its branches anastomose in different manners with each other; many of them present numerous and strongly-marked *flexuosities;* they are distributed to all the parts of the body, and effect in each a particular disposition; lastly, they terminate by a communication with the veins and the lymphatic vessels. In other respects, the structure of the *aorta* is very similar to that of the pulmonary artery; only its middle membrane is much thicker and more elastic. Almost in its whole length the *aorta* is accompanied by filaments proceeding from the ganglions of the grand sympathetic: these filaments seem to spread in its sides.

Course of the Arterial Blood in the Pulmonary Veins.

In treating of the course of the blood in the pulmonary artery, we have shown how this liquid reaches the last division of this vessel; the blood does not stop there, it passes into the radicles of the pulmonary veins, and very soon reaches the trunk of these veins; in this passage it presents a gradually accelerated motion, in proportion as it passes from the small veins into the larger; finally, it does not at all flow by jerks, and it appears nearly equally rapid in the four pulmonary veins.

Passage of the blood through the capillaries of the lungs.

But what occasions the progression of the blood in these veins? The cause which presents itself naturally to the mind is the contraction of the right ventricle, and the pressure of the sides of the pulmonary artery; indeed, after having pressed the blood through the last divisions of the pulmonary artery, we cannot see why these two causes may not continue to make it move in the pulmonary veins.

Such was the opinion of Harvey, who first demonstrated the true course of the blood; but it appears that modern Physiologists have found it too simple; and it is now generally received that being once arrived in the last divisions of the pulmonary artery and into the first radicles of the veins, or, according to the adopted language, into the capillaries of the lungs, the heart has no more influence on the motion of the blood: it then moves only by the proper action of the small vessels that it traverses. This idea of the action of the capillary vessels upon the blood is the most important at present in Physiology; after the vital properties this presents the greatest facility for the explanation of the most obscure phenomena.

Capillary Impulse examined.

Let us then examine it with attention; and, first, has this action of the capillaries been observed by any person? Is it sensible? No: no one has ever seen it; it is merely imagined.

But suppose this action of the capillaries admitted: in what does it consist? Is it a contraction more or less considerable, by which they press out the blood with which they are filled? I am willing to believe that, in contracting, they will press out the blood: but there is no reason why they should direct it more towards the arteries than towards the veins. Then, the small vessel being once empty, how is it filled again? This can take place only insomuch as the heart affords new blood, or by its dilatation attracts that placed in the vessels which are near: in this supposition it would attract that of the veins as well as that of the arteries. Thus, in admitting what is certainly a gratuitous supposition, that the capillary vessels dilate and contract alternately, still we will not have an explanation of the function which is attributed to them. In order that they may have this use, it would be necessary for each capillary to be disposed in a manner similar to the heart; that it should be composed of two parts, one of which would contract whilst the other should dilate, and that there should be a valve between them, like, or analogous to the mitral: even with this disposition we could not explain the uniform flowing of the blood in these vessels, and in the pulmonary veins.

In whatever point we examine this action of the capillaries, every thing is vague and contradictory; besides, in reptiles, in which we can see with facility the blood of the pulmonary artery pass into the veins by the aid of a microscope, there is no motion perceived in the place where the artery changes to a vein; and nevertheless the flowing of the blood is perfectly manifest and equally rapid.

We may then conclude that the action of the pulmonary capillaries upon the motion of the blood in the pulmonary veins is a gratuitous supposition, a piece of imagination; in a word, a chimera; and that the true cause of the passage of the blood from the artery into the pulmonary veins is the contraction of the right ventricle.

I am far from thinking that the small vessels allow the blood always to pass in the same manner; we have a proof of the contrary at each inspiration or expiration. The passage is easy when the lungs are distended by the air;

if the breast is contracted and the lungs contain little air, it becomes more difficult. Besides, it is extremely probable that they dilate or contract, according to the quantity of blood that traverses the lungs, and perhaps by many other circumstances. I believe that, according as they are distended or contracted, they must influence the flowing of the liquid that traverses them; but that is far from believing them capable of modifying the circulation of the blood, or considering them as the sole agents of its motion.

Influence of the eighth pair upon the course of the blood in the lungs.

The eighth pair, however, appear to have a great influence upon the passage of the blood across the lungs. It very probably modifies the disposition of the capillaries of these organs.

In dead bodies, when an injection of water is thrown into the pulmonary artery, it immediately flows into the veins; a part of it, however, passes into the bronchial cells, mixes with the air, and forms with this fluid a slight froth; another part of it flows and filters into the cellular tissue of the lungs.

After some time, when this filtration has become considerable, it is impossible to make an injection pass into the pulmonary veins: analogous phenomena happen, when, in place of water, blood is injected into the pulmonary artery. These phenomena, as is seen, have a great deal of analogy with those which the section of the eighth pair produces upon living animals.

The pulmonary veins are not so capable of extension as the other veins. The blood which traverses them also passes quickly into the left auricle.

Absorption of the Pulmonary Veins. (87)

Absorption of the pulmonary veins.

The pulmonary veins absorb the same as other veins, and transport to the heart the substances which are in contact with the spongeous tissue of the lobules of the lungs.

One inspiration of air charged with odorous particles, is sufficient for its effects to become manifest in the animal economy.

The deleterious gases, medicinal substances floating in the air, contagious miasmata, certain poisons or medicines

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(87) See our note above, on pulmonary transhalation.

applied upon the tongue, produce effects in this manner of astonishing rapidity.

The manner in which this absorption takes place is not better known than that of the general venous absorption.

Passage of the Arterial Blood through the left Cavities of the Heart.

The mechanism by which the blood traverses the left auricle and ventricle is the same as that by which the venous blood traverses the right cavities. Action of the left ventricle and auricle

When the left auricle dilates, the blood of the four pulmonary veins enters and fills it; when it contracts, part of the blood passes into the ventricle, and part flows back into the pulmonary veins; when the ventricle dilates, it receives the blood which comes from the auricle, and a small quantity of that of the *aorta;* when it contracts, the mitral valve is raised, it shuts the *auriculo-ventricular* opening, and the blood not being able to return into the auricle, it enters into the aorta by raising the three sigmoid valves, which were shut during the dilatation of the ventricle.

It is necessary to remark, however, that the fleshy columns having no existence in the auricle, their influence cannot exist as in the right, and the arterial ventricle being much thicker than the venous, it compresses the blood with a much greater force than the right, which was indispensable on account of the distance to which it has to send this liquid.

Course of the Blood in the Aorta, and its divisions.

Notwithstanding the differences which exist between this and the pulmonary artery, the phenomena of the motion of the blood are nearly the same in both: thus a ligature being applied upon this vessel, near the heart, in a living animal, it contracts in its whole length, and, except a small quantity that remains in the principal arteries, the blood passes immediately into the veins. Course of the blood in the aorta

Some authors doubt the fact of the contraction of the arteries; the following experiment may be made to convince them: uncover the carotid artery of a living animal the length of several inches; take the transverse dimension of the vessel with compasses, tie it at two different points at the same time, and you may then have any length whatever of artery full of blood; make a small opening in the sides of this portion of the artery, you will immediately see almost the whole of the blood pass out, and it will even spout to a certain distance. Then measure the breadth with the compasses, and there will be no doubt of the artery being much contracted, if the rapid expulsion of the blood has not already convinced you. This experiment also proves, contrary to the opinion of Bichât, that the force with which the artery contracts is sufficient to expel the blood that it contains. I shall just now give other proofs of it. This almost total expulsion cannot happen during life, because the left ventricle sends new blood at every instant into the aorta, and this blood replaces that which constantly passes into the veins.

Every time that the ventricle injects blood into the aorta, both it and its divisions are extended to a certain degree; but the dilatation becomes weaker in proportion as the arteries become smaller; it ceases entirely in those that are very small. It is seen that these phenomena are the same which we described in speaking of the pulmonary artery; the explanation that we gave of it ought to be repeated here.

The polish of the interior surface of the arteries must be very favourable to the motion of the blood: we at least know, that if it becomes less, as happens in several diseases, the flowing of this liquid is more or less incommoded, and it may even stop entirely. This is probably the cause why the blood does not flow long through a tube into which the open extremity of an artery is introduced.

Very probably the friction of the blood against the sides of the arteries, its adhesion to them, its viscosity, &c., have also a great influence upon its motion; but these different causes, either united or separated, are inappreciable.

Besides these phenomena common to the two arteries, there are some which are peculiar to the aorta, and which depend upon the anastomoses existing between its branches, and the multiplied bendings which are in most of them.

Effects of the curvature of arteries.

Whenever an artery presents a flexure, every time that the ventricle contracts, there is a tendency to become straight, or even a real straightening of the vessel,—a tendency which manifests itself by an apparent motion, called by some authors *locomotion of the artery*, and which has been regarded as the principal cause of the pulse. This motion is so much stronger as it is observed nearer the heart, and in a larger artery. The arch of the aorta is the place where it is the most apparent; it can be easily explained.

One consequence to be deduced from this fact is, that it is mechanically impossible that the curvatures of arteries should not retard the course of the blood, particularly when they are angular. Bichât deceived himself completely in this respect, when he asserted that the arterial bendings have no influence upon it. That, he affirmed, could not happen but in proportion as the arteries were empty, when the blood came from the heart; but as they are always full, such an effect could not take place. But since each bending consumes a part of the force which is employed in straightening the vessel, or even in tending to straighten it, there is then less force left for the progress of the liquid, and consequently its motion is retarded.

The influence of different anastomoses are more easily explained; we see that they are useful, and that, by their assistance, the arteries mutually supply each other in the distribution of the blood to the organs; but it cannot be said exactly what modifications they impress upon the motion of the blood. Effects of anastomoses.

If the dimensions, the curvatures, and probably, the anastomoses of the arteries have so great an influence upon the course of the blood, it is impossible that all the organs, where each of these things presents a different disposition, can receive blood with the same quickness, and, consequently, with the same force. For example, the brain has four large arteries for itself; but these arteries make numerous windings, and even present several angular bendings before entering the skull; and when they have reached it, they very frequently anastomose, and do not enter into the tissue of the organ until they have become extremely small: the blood, then, must enter but slowly. On the contrary, the kidneys have only one artery, short and thick, which enters into their parenchyma when its divisions are still very large: the blood, then, must traverse it with rapidity, &c.

Thus, by the concurrence of circumstances, which modify the course of the arterial blood, a very complicated problem of hydraulics is resolved; namely, the distribution (continued, but variable as to quantity and velocity) of a fluid contained in a system of tubes, the parts of which are very unequal in length and capacity, by means of one alternate agent of impulsion.

We have placed the dilatation and contraction of the arteries amongst the number of the phenomena of the course of the arterial blood.

The existence of these phenomena are not admitted by Bichât. This author will not allow that the arteries dilate in the instant when the ventricle contracts, and he positively denies that they contract and press the blood in all directions; I believe, nevertheless, that with a little attention it is possible to see these phenomena distinctly in an artery laid bare. For example, they are evident in the large arteries, such as the abdominal, or pectoral aorta, particularly in the large animals; but to make them apparent in the smaller arteries, the following experiment must be made.

Experiments upon the course of the blood in the aorta.

Lay bare to a certain extent the crural vein and artery of a dog, then pass a ligature behind these two vessels, the extremities of which must be fastened strongly to the posterior part of the thigh; in this manner the arterial blood will arrive at the member only by the crural artery, and will return to the heart only by the vein: measure the diameter of the artery with compasses, then press it between the fingers to intercept the current of the blood, and its volume will diminish by little and little below the place compressed, and the blood that it contained will pass out. Then, by ceasing to compress it, let the blood enter it anew; it will be seen to extend at each contraction of the ventricle, and will reassume its former dimensions.

But though I consider as certain the dilatation and contraction of the arteries, I am far from thinking, with some authors of the last age, that they dilate of themselves, and that they contract like the muscular fibres; on the contrary, I believe that they are passive in both cases, that is, their dilatation and contraction are only the effect of the elasticity of their sides put in play by the blood which is continually injected into their cavity by the heart.

Experiments upon the arteries.

In this respect there is no difference between the large and the small arteries. I have proved, by direct experiments, that the arteries nowhere present any indication of irritability, that is, they remain immoveable under the action of sharp instruments, of caustics, and of the galvanic current.

From not acknowledging the contractility of the arterial sides, Bichât necessarily rejected the important phenomena which is the effect of them. He did not believe that the blood flowed, or moved in a continued manner in these vessels; he thought that the whole mass of liquid was displaced at the instant in which the ventricle contracts, and immoveable at the instant of its relaxation, as would happen if the sides of the arteries were inflexible. Opinion of Bichât upon the course of the arterial blood.

This opinion has been lately maintained by Doctor Johnson, an English physician; he has even caused a machine to be constructed which, he says, renders this evident: but it is sufficient to open an artery in a living animal to see that the blood passes out in a continued stream; in jets if the artery is large, and uniform if it is small. Now, the action of the heart not being continued, it cannot produce a continued stream. The arteries must then act upon the blood.

The elasticity of the sides of the arteries represents that of the reservoir of air in certain pumps that play alternately, and which nevertheless furnish the liquid in a continued manner; and it is generally known in mechanics that every intermittent movement may be transformed into a continued movement by employing the force which produces it to compress a spring which afterwards acts with continuity. Elasticity of the sides of the arteries.

Passage of the Blood of the Arteries into the Veins.

When, in the dead body, an injection is thrown into an artery, it immediately returns by the corresponding vein: the same thing takes place, and with still more facility, if the injection is thrown into the artery of a living animal. In cold-blooded animals, the blood can be seen, by the aid of a microscope, passing from the arteries into the veins. The communication between these vessels is then direct, and very easy; it is natural to suppose that the heart, after having forced the blood to the last arterial twigs, continues to make it move into the venous radicles, and even into the veins. Harvey, and a great number of celebrated anatomists, thought so. Lately, Bichât has been strongly against this doctrine; he has limited the influence of the blood; he pretends that it ceases entirely in the place where the arterial is changed into venous blood, that is, in the numerous small vessels that terminate the arteries and commence the veins. In this place, according to him, the *action of the small vessels alone*, is the cause of the motion of the blood.

Passage of the blood from the arteries into the veins.

We have already opposed this supposition in speaking of the course of the blood in the veins: the same reasoning can be applied perfectly well here. Bichât says that this action of the capillaries consists of a *sort of oscillation, of an insensible vibration of the vascular parietes.* Now, I ask how an oscillation, or an insensible vibration of the sides, can determine the motion of a liquid contained in a canal? Again, if this vibration is insensible, who discovered it? We ought not to confuse a simple question by suppositions that are vague and without proof, but to admit the explanation that naturally presents itself to the mind; viz. that the principal cause which makes the blood of the arteries pass into the veins, is the contraction of the heart. I give here, besides, some experiments which appear to render the phenomenon evident. (88)

(88) I remember to have read in the journals, a very warm discussion of this point, maintained between Dr. Johnson, and my excellent friend Dr. Hastings of Worcester. I confess, however, that though impressed with the highest respect for the talents and zeal of both parties, I never could see how their machinery was to be applied to the human body; since both parties were bound by their hypotheses to admit, at least, the irritable or contractile power of the heart, and also of the capillaries, neither of which could, therefore, by any means, be represented in their apparatus. Neither Dr. Johnson nor Dr. Hastings could have any other object than the service of truth, and the numerous writers who have arranged themselves on their respective sides, are entitled to the same credit; their multitude being only a proof of the importance and difficulty of the question. The student, probably, will be more apt to take a side, than to sit coolly down, declaring the point indeterminable; but I have drawn up the following synopsis of the arguments, for, and against, the contractility of arteries, that he may choose neither of the three ways empty handed.

ARGUMENTS FOR AND AGAINST THE CONTRACTILITY OF ARTERIES.

1. The arteries are productions from the heart, which is distinctly muscular.	1. The aorta arise by a peculiar cartilaginous ring from the ventricle.
2. Fœtal circulation has been supported by arteries alone, when the heart was wanting.	2. Monsters prove nothing.
3. In many of the worm tribe there is either no heart, or the heart is an artery, yet in these circulation goes on.	

After having passed a ligature round the thigh of a dog, as I just now described, that is, without including the Experiments upon the pas-

4. Verdschuir and Hastings have seen all the arteries contract on the application of a stimulus: and most unprejudiced writers, as Haller, Bichât, admit of this property in the capillaries. Now, as a capillary has no distinct beginning, it seems but fair to extend the property to the whole vascular system.	4. Many eminent anatomists deny the fact; even Haller denies it in the larger vessels.
5. A large artery, if cut, can be felt contracting on the finger: as in the shark.	5. The cut artery contracts from mere organic contractility; indeed for the same reason as it retracts.
6. The fibrous texture, so common to muscles, can easily be pointed out in arteries.	6. Fibres are no certain proof of muscularity.
7. Arteries are richly furnished with meshes of nerves: if not for contraction, what is the use of this apparatus?	7. Cartilages have nerves; but do not therefore contract.
8. When an artery becomes ossified. The circulation below it stops.	8. Bichât's experiment of inserting a glass tube.
9. In paralysis, the force, and often the number of the pulsations of arteries in the affected side is diminished: Now this is just what happens to muscles involuntarily from the same cause, and cannot be explained in any other way; for relaxing tubes not contractile, ought to permit a larger wave of blood to enter.	
10. In apoplexy, the whole circulation is affected, and often becomes extremely irregular in its distribution.	
11. Topical congestion from any cause, as stimulation, friction, blushing, lascivious ideas, &c., must always arise from an action in the vessels of the part affected. Indeed, all medicine, except the exhibition of general stimulants, is founded on this fact; since almost every class of medicines acts by determining an increased action of the vessels of a given organ.	
12. The removal of topical congestion, or plethora, by remedies, proves the same thing.	
13. The lymphatics, a very similar	13. The lymphatics resemble veins

sage of the blood from arteries into veins.

crural artery or vein, apply a ligature separately upon the vein near the groin, and then make a slight opening in this vessel: The blood will immediately escape, forming a considerable jet. Then press the artery between the fingers to prevent the arterial blood from reaching the member, the jet of venous blood will not stop on this account, it will continue some instants; but it will become less and less, and the flowing will at last stop, though the whole length of the vein is full. If the artery is examined during the production of these phenomena, it will be seen to contract by degrees, and will become completely empty. The blood of the vein then stops: and at this period of the experiment, if you cease to compress the artery, the blood injected by the heart will enter, and as soon as it has arrived at the last divisions, will begin to flow again at the opening of the vein, and by little and little the jet will be established as before.

Now, compress the artery anew until it has emptied itself, then let the arterial blood enter it slowly: in this

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system to the arteries, contract distinctly on the application of a stimulus.	rather than arteries; resemblance is no proof.
14. Certain mechanical irritations of the brain, spinal chord, or nerves, modify the circulation, and differently in different parts.	
15. The passions affect individual secretions, as the tears, which are furnished by certain arteries.	
16. The ligature of a nerve lessens the secretion of the gland to which it goes.	
17. Hæmorrhages are daily stopped by the application of stimuli as effectually as by tying the artery.	
18. The arteries are found empty after death. If they are not contractile, what empties them?	18. The arteries are emptied after death, by the power of the heart.
19. When the aorta has been tied below the heart, the arteries are still found empty.	19. They are emptied by organic insensible contractility.
20. The force of the blood in the smallest arteries: The pulse.	20. Parry has proved the mechanical origin of the pulse.
21. An artery included between two ligatures pulsates: and when first exposed to the air, contracts half its diameter.—*Tiedeman vers.* 12. p. 33.	21. Lamure was mistaken in the experiment of including an artery between two ligatures: the vessel merely undergoes a local displacement.

case the flowing of the blood will take place, but there will be no jet until the artery be entirely free. Analogous results will be obtained in throwing an injection of tepid water into the artery in place of letting the blood into it; the greater the force is with which the injection is thrown, the liquid will pass the quicker through the vein.

Communication between the arteries and the lymphatic vessels.

In speaking of the lymphatic vessels, I said that they communicate with the arteries, and that injections easily pass from the one to the other; this communication becomes still more evident when some saline or colouring substance is injected into the veins of a living animal. I have ascertained several times that these substances pass into the lymphatics in less than two or three minutes, and that it is easy to demonstrate their presence in the lymph that is extracted from these vessels.

Swelling of some organs by the accumulation of blood.

As long as the veins that proceed from the organs are free, the blood that arrives in them by the arteries traverses their parenchyma, and does not accumulate in them; but if the veins are compressed, or cannot empty themselves of the blood that they contain, the blood always arriving by the arteries and finding no place in the veins, accumulates in the tissue of the organ, distends the blood vessels, and augments more or less its volume, particularly if its physical properties can undergo these changes. This phenomenon may be observed in many organs; but as it is more apparent in the brain, it has been oftener remarked there.

This swelling of the brain by the difficulty of the circulation, happens every time that the flowing of the blood is more difficult in the lungs, and as that generally takes place in the expiration, the brain swells in this instant, so much more in proportion as the expiration is more complete and of longer continuation. The swelling is more marked in young animals, in which the brain receives a greater proportion of arterial blood.

Remarks on the Movements of the Heart.

A. The right auricle and ventricle, and the left auricle and ventricle, the action of which we have studied separately, in reality form only one organ, which is the heart.

The auricles contract and dilate together; the same thing takes place with the ventricles, whose movements are simultaneous.

When the contraction of the heart is spoken of, that of the ventricle is understood. Their contraction is called *systole*, their dilatation *diastole*.

Motion of the heart.

B. Every time that the ventricles contract, the whole of the heart is rapidly carried forward, and the point of this organ strikes the left lateral side of the chest, opposite the interval of the sixth and seventh true ribs. (89)

This motion forward of the heart in the systole, has given place to a long and violent controversy; some pretended that the heart became short by contraction; others pretended that it was prolonged, and that it necessarily must be so, because without that it could not strike the side of the thorax, since it is distant from it more than an inch in the diastole. A great number of animals were sacrificed to no purpose, in order to study the movement of the heart; at the same instant to some it was shortened, to others it was prolonged. What could not be explained by experiments was done by very simple reasoning. Bassuel entered into the dispute, and showed that if the heart was prolonged in the systole, the mitral and tricuspid valves, kept down by the fleshy columns, could not shut the *oriculo ventricular openings*.

The partisans of the prolongation did not persist any longer; but it remained to be shown how, in the shortening of the ventricles, the heart could be carried forward.

Senac showed that this depended on three causes: 1st, the dilatation of the auricles, which takes place during the contraction of the ventricles; 2d, the dilatation of the aorta and the pulmonary artery, by the introduction of the blood from the ventricles; 3d, the straightening of the arch of the aorta by the effect of the contraction of the left ventricle.

Number of the motions of the heart in a minute.

C. The number of the pulsations of the heart is considerable; it is generally greater in proportion as the person is younger.

At birth it is from - -	130 to 140 in a minute.
At one year - - - -	120 to 130.
At two years - - - -	100 to 110.
At three years - - -	90 to 100.
At seven years - - -	85 to 90.
At fourteen years - -	80 to 85.
At adult age - - - -	75 to 80.
At first old age - - -	65 to 75.
At confirmed old age -	60 to 65.

(89) Rather read, opposite the interior of the fifth and sixth true ribs.

But these numbers vary according to an infinity of circumstances, sex, temperament, disposition, &c.

The affections of the mind have a great influence upon the rapidity of the contractions of the heart; every one knows that even a slight emotion immediately modifies the contractions, and generally accelerates them. In this respect great changes take place also by diseases.

D. Many researches have been made to determine with what force the ventricles contract. In order to appreciate that of the left ventricle, an experiment has been made, which consists in crossing the legs, and placing upon one knee the ham of the other leg, with a weight of 55 pounds appended to the extremity of the foot. This considerable weight, though placed at the extremity of such a long lever, is raised at each contraction of the ventricle, on account of the tendency to straighten the accidental curvature of the popliteal artery, when the legs are crossed in this manner. Force with which the ventricle contracts.

This experiment shows that the force of contraction of the heart is very great; but it cannot give the exact value of it. Mechanical Physiologists have made great efforts to express it in numbers. Borelli compares the force which keeps up the circulation to that which would be necessary to raise 180,000 pounds; Hales believes it to be 51 pounds 5 ounces; and Keil reduces it to from 15 to 8 ounces. Where shall we find the truth in these contradictions?

It seems impossible to know exactly the force developed by the heart in its contraction; it very probably varies according to numerous causes, such as age, the volume of the organ, the size of the individual, the particular disposition, the quantity of blood, the state of the nervous system, the action of the organs, the state of health or of sickness, &c.

All that has been said of the force of the heart relates only to its contraction, its dilatation having been considered as a passive state, a sort of repose of the fibres; however, when the ventricles dilate it is with a very great force, for example, capable of raising a weight of twenty pounds, as I have many times observed in animals recently dead. When the heart of a living animal is taken hold of by the hand, however small it may be, it is impossible by any effort to prevent the dilatation of the ventricles. The dilatation of the heart, then, cannot be considered as a state of inaction or repose.

E. The heart moves from the first days of existence of the embryo to the instant of death by decrepitude.

Why does it move? This question has been asked by ancient and modern philosophers and physiologists. The *wherefore* of phenomena is not easy to be given in physiology; almost always what is taken for such is only in other terms the expression of the phenomena; but it is remarkable how easily we deceive ourselves in this respect: one of the strongest proofs of it is afforded by the different explanations of the motion of the heart.

Cause of the motions of the heart.

The ancients said that there was a *pulsific virtue* in the heart, a *concentrated fire*, that gave motion to this organ. Descartes imagined than *an explosion as sudden as that of gunpowder* took place in the heart. The motion of the heart was afterwards attributed to the *animal spirits*, to the *nervous fluid*, to the *soul*, to the *præses of the nervous system*, to the *archea*: Haller considered it as an effect of irritability. Lately, M. Legallois has endeavoured to prove, by experiments, that the principle or cause of the motion of the heart has its seat in the spinal marrow.

Experiments of Legallois upon the motion of the heart.

These experiments of M. Legallois consist in destroying by degrees the spinal marrow in living animals, by the introduction of a metallic rod into the vertebral canal.

The result is, that the force with which the left ventricle contracts diminishes according as the destruction of the marrow proceeds, and when it is completely destroyed the heart has no longer sufficient force to keep up the circulation, and to press the blood to the extremities of the members.

M. Legallois has concluded, from these experiments, that have been multiplied and varied in a very ingenious manner, that the cause of the motion of the heart is in the spinal marrow; and, as it was remarked to him that this organ contracts long after the complete destruction of the marrow, and that its motions even continue regularly long after it has been completely separated from the body, M. Legallois replied that these motions were not the real contraction of the heart, but only an effect of the irritability of the organ.

In order to have this explanation admitted, M. Legallois should have shown by experiments in what the irritability of muscular fibres differs from their contraction: this important distinction not being established, nothing, in my opinion, can be concluded from the interesting labours of M. Legallois, except that the spinal marrow has an influence upon the contraction of the heart; but we cannot thence deduce that this is the cause of the motion of the heart.

The organs that transmit the influence of the spinal marrow, and of the brain to the heart, are nervous filaments proceeding from the eighth pair; and, perhaps, a great number of threads of the cervical ganglions of the grand sympathetics.

M. Dupuytren and I, some years ago, endeavoured to determine by the extraction of the cervical ganglions, and even by the first thoracic, what was the action of the ganglions upon the motion of the heart, but we obtained nothing satisfactory; the animals almost all died in consequence of the inevitable wound for the extraction. We never remarked any direct influence upon the heart. Influence of the ganglions upon the motion of the heart.

Remarks upon the circular motion of the Blood, or the Circulation.

We now know all the links of the circular chain that the sanguiferous system represents: we know how the blood is carried from the lungs towards all the other parts of the body, and how it returns from these parts to the heart. Let us examine these phenomena in a general manner, in order to show the most important.

A. The quantity of blood contained in the system is very considerable. It has been estimated by several authors at from 24 to 30 pounds. This value cannot be at all exact, for the quantity of blood varies according to numerous causes. Total quantity of blood.

The relation of the mass of the arterial with that of the venous blood, is somewhat better known. This last, contained in vessels larger than that of the arteries, is necessarily in greater quantity, though we cannot say exactly how much greater its mass is than that of the arterial blood.

B. The circulatory path of the blood being continuous, and the capacity of the canal variable, the rapidity of this fluid must be variable also; for the same quantity must pass through all the points in a given time: observation confirms this. The rapidity is great in the trunk, and the principal divisions of the pulmonary artery and aorta; Rapidity of the motion of the blood.

it diminishes much in the secondary divisions; it diminishes still more at the instant of the passage from the arteries into the veins; it continues to augment in proportion as the blood passes from the roots of the veins into larger roots, and lastly into the large veins; but the rapidity is never so great in the venæ cavæ as in the aorta. In the trunks and the principal arterial divisions, the course of the blood is not only continued under the influence of the contraction of the arteries, but, besides, it flows in jerks by the effect of the contraction of the ventricles. This jerking manifests itself in the arteries by a simple dilatation in those that are straight, and by a dilatation and tendency to straighten in those which are flexuous.

Different modes of the motion of the blood.

Of the pulse.

The pulse is formed by the first of these phenomena, to which the second is sometimes joined. It is not easy to study, in man or in the animals, except where the arteries are laid close upon a bone, because they do not then retire from under the finger when it is placed upon them, as happens to arteries in soft parts.

In general, the pulse makes known the principal modification of the contraction of the left ventricle, its quickness, its intensity, its weakness, its regularity, its irregularity. The quantity of the blood is also known by the pulse. If it is great, the artery is round, thick, and resisting. If the blood is in small quantity, the artery is small and easily flattened. Certain dispositions in the arteries have an influence also upon the pulse, and may render it different in the principal arteries.

Supposed influence of the pulsation of the arteries upon the action of organs.

C. The beating of the arteries is necessarily felt in the organs which are next them, and so much more in proportion as the arteries are more voluminous, and as the organs give way with less facility. The jerk which they undergo is generally considered as favourable to their action, though no positive proof of it exists.

In this respect none of the organs ought to be more affected than the brain. The four cerebral arteries unite in circles at the base of the skull, and raise the brain at each contraction of the ventricle, as it is easy to be convinced of by laying bare the brain of an animal, or by observing this organ in wounds of the head. Probably, the numerous angular bendings of the internal carotid arteries, and of the vertebrals before their entrance into the skull, are useful for moderating this shaking; these bendings must also necessarily retard the course of the blood in these vessels.

When the arteries penetrate in a voluminous state into the parenchyma of the organs, as the liver, the kidneys, &c., the organ must also receive a jerk at each contraction of the heart. The organs into which the vessels enter after being divided and subdivided, can suffer nothing similar.

D. From the lungs to the left auricle the blood is of the same nature; however, it sometimes happens that it is not the same in the four pulmonary veins. For instance, if the lungs are so changed that the air cannot penetrate into the lobules, the blood which traverses them will not be changed from venous to arterial blood; it will arrive at the heart without having undergone this change; but in its passage through the left cavities it will be intimately mixed with that of the lungs opposite. The blood is necessarily homogeneous from the left ventricle to the last divisions of the aorta; but, being arrived at these small divisions, its elements separate; at least there exists a great number of parts, such as the serous membranes, the cellular tissue, the tendons, the aponeuroses, the fibrous membranes, &c., into which the red part of the blood is never seen to penetrate, and the capillaries of which contain only serum. Nature of the blood in the different parts of the circle through which it passes.

This separation of the elements of the blood takes place only in a state of health; when the parts that I have mentioned become diseased, it often happens that their small vessels contain blood, possessed of all its characteristic properties. Separation of the elements of the blood of the capillaries.

There have been endeavours to explain this particular analysis of the blood by the small vessels. Boerhaave, who admitted several sorts of globules of different sizes in the blood, said, that globules of a certain largeness could only pass into vessels of an appropriate size: we have seen that globules, such as they were admitted by Boerhaave, do not exist.

Bichât believed that there existed in the small vessels a particular sensibility, by which they admitted only the part of the blood suitable to them. We have already frequently contested ideas of this kind; neither can they be admitted here, for the most irritating liquids introduced into the arteries pass immediately into the veins, without any opposition to their passage by the capillaries.

Elements of the blood that escape from the small vessels.

E. The elements of the blood separate in traversing the small vessels; sometimes the serum escapes, and spreads upon the surface of a membrane; sometimes the fatty matter is deposited in cells; here the mucus, there the fibrine; elsewhere are the foreign substances, which were accidentally mixed with the arterial blood. In losing these different elements, the blood assumes the qualities of venous blood. At the same time that the arterial blood supplies these losses, the small veins absorb the substances with which they are in contact. In the intestinal canal, for example, they absorb the drinks; on the other hand, the lymphatic trunks pour the lymph and the chyle into the venous system; it is certain, then, that the venous blood cannot be homogeneous, and that its composition must be variable in the different veins; but, having reached the heart, by the motions of the right auricle and ventricle, and the disposition of the fleshy columns, the elements all mix together, and when they are completely mixed, they pass into the pulmonary artery.

F. A general law of the economy is, that no organ continues to act without receiving arterial blood; from this results, that all the other functions are dependent on the circulation; but the circulation, in its turn, cannot continue without the respiration by which the arterial blood is formed, and without the action of the nervous system, which has a great influence upon the rapidity of the flowing of the blood, and upon its distribution in the organs. Indeed, under the action of the nervous system, the motions of the heart, and consequently the general quickness of the course of the blood, are quickened or retarded. Thus, when the organs act voluntarily or involuntarily, we learn from observation, that they receive a greater quantity of blood without the motion of the general circulation being accelerated on that account; and if their action predominates, the arteries which are directed there, increase considerably. If, on the contrary, the action diminishes, or ceases entirely, the arteries become smaller, and permit only a small quantity to reach the organ. These phenomena are manifest in the muscles: the circulation becomes more rapid in them when they contract; if they are often contracted, the volume of their arteries increases; if they are paralysed, the arteries become very small, and the pulse is scarcely felt.

Influence of the nervous system upon the motions of the blood.

The circulation, then, may be influenced by the nervous system in three ways: 1st, by modifying the motions of the heart; 2dly, by modifying the capillaries of the organs, so as to accelerate the flowing of the blood in them; 3dly, by producing the same effects in the lungs, that is, by rendering the course of the blood more or less easy through this organ.

The acceleration of the motions of the heart becomes sensible to us by the manner in which the point of this organ strikes the walls of the chest. The difficulty of the capillary circulation is discovered by a feeling of numbness, and a particular prickling; and when the pulmonary circulation is difficult, we are informed of it by an oppression or sense of suffocation, more or less strong.

Instinctive feelings that give notice of the modifications of the circulation.

Probably the distribution of the filaments of the great sympathetic on the sides of the arteries has some important use; but this use is entirely unknown; we have received no light on the point by any experiment.

Of Transfusion of Blood, and of the Infusion of Medicines.

Such is the opposition that men of genius meet sometimes from their contemporaries, that Harvey was thirty years before he could get his discovery admitted, though the most evident proofs of it were every where perceptible; but as soon as the circulation was acknowledged, people's minds were seized with a sort of delirium: it was thought that the means of curing all diseases was found, and even of rendering man immortal. The cause of all our evils was attributed to the blood; in order to cure them, nothing more was necessary but to remove the bad blood, and to replace it by pure blood, drawn from a sound animal.

Transfusion of the blood.

The first attempts were made upon animals, and they had complete success. A dog having lost a great part of its blood, received, by transfusion, that of a sheep, and it became well. Another dog, old and deaf, regained, by this means, the use of hearing, and seemed to recover its youth. A horse of twenty-six years having received in his veins the blood of four lambs, he recovered his strength.

Transfusion of blood in animals.

Transfusion was soon attempted upon man. Denys and Emerez, the one a physician, the other a surgeon of Paris, were the first who ventured to try it. They intro-

Transfusion of blood in man.

duced into the veins of a young man, an idiot, the blood of a calf, in greater quantity than that which had been drawn from him, and he appeared to recover his reason. A leprous person, and a quartan ague, were also cured by this means; and several other transfusions were made upon healthy persons without any disagreeable result.

However, some sad events happened to calm the general enthusiasm caused by these repeated successes. The young idiot we mentioned fell into a state of madness a short time after the experiment. He was submitted a second time to the transfusion, and he was immediately seized with a *Hœmaturia*, and died in a state of sleepiness and torpor. A young prince of the blood royal was also the victim of it. The parliament of Paris prohibited transfusion. A short time after, G. Riva, having, in Italy, performed the transfusion upon two individuals, who died of it, the pope prohibited it also.

From this period, transfusion has been regarded as useless and even dangerous; however, as it appears to have succeeded in certain cases, it would be interesting that some able person should make it the object of a series of experiments. I have had the opportunity to make a certain number, and I have not found that the introduction of the blood of one animal into the veins of another had any serious inconvenience, even when, by this means, the blood is much augmented.

Infusion of medicines. A short time after the discovery of the circulation, attempts were made to carry medicines directly into the veins: advantages arose from it in certain cases, and disadvantages in others: this means soon fell into disuse; but it has been, and is still employed, with success, in experiments upon animals. It is an excellent plan for determining immediately the action of a medicine, or of a poison. It is upon this plan that medicines are administered to large animals at the veterinary school of *Copenhagen;* there is found in it the advantage of a very rapid action, and a great economy in the quantity of medicines employed. A cautious use of this means might be useful in medicine, in certain extreme cases in which ordinary aid is insufficient.

OF THE SECRETIONS.

Passing through the innumerable small vessels by which the arteries and the veins communicate, a part of the elements of the blood is spread over all the surfaces of the body, interior and exterior; another is deposited in the small hollow organs situated in the skin, and in the mucous membranes; lastly, a third enters into the parenchyma of the organs called *glands*, undergoes in them a particular elaboration, and spreads itself afterwards, in certain circumstances, at the surface of the mucous membranes, or the skin. Distribution of the elements of the blood in the capillaries.

The generic name of *secretion* is given to this phenomenon, by which a part of the blood escapes from the organs of circulation, and diffuses itself without or within; either preserving its chemical properties, or dispersing after its elements have undergone another order of combinations. Secretions

The secretions are generally divided into three sorts; the *exhalations*; the *follicular secretions*, and the *glandular secretions;* but this division, in respect of secreting organs and secreted fluids, leaves much to be supplied. Many secreting organs can be referred neither to the follicles nor the glands, and what are generally called *follicles* or *glands* are organs so different from each other, by their form, their structure, and the fluids which they secrete, that it would have been perhaps convenient not to confound them under the same denomination. Division of the secretions.

However, not to depart too far from the received ideas, we shall speak of the secretions according to this classification. This article shall be short; for were we to extend it as far as it is susceptible, we would far surpass the bounds that we have prescribed to ourselves in this work.

Of the Exhalations.

The exhalations take place as well within the body as at the skin, or in the mucous membranes; thence their division into *external* and *internal.* Exhalations.

Internal Exhalations.

Wherever large or small surfaces are in contact, an exhalation takes place; wherever fluids are accumulated in a cavity without any apparent opening, they are deposit- Internal exhalations.

ed there by exhalations: the phenomenon of exhalation is also manifested in almost every part of the animal economy. It exists in the serous, the synovial, the mucous membrânes; in the cellular tissue, the interior of vessels, the adipose cells, the interior of the eye, of the ear, the parenchyma of many of the organs, such as the thymus, thyroid glands, the *capsulæ suprarenales*, &c., &c. It is by exhalation that the watery humour, the vitreous humour, the liquid of the labyrinth, are formed and renewed. The fluids exhaled in these different parts have not all been analyzed; amongst those that have been, several approach more or less to the elements of the blood, and particularly to the serum; such are the fluids of the serous membranes of the cellular tissue, of the chambers of the eye; others differ more from it, as the synovia, the fat, &c.

Serous Exhalation.

Serous cavities.

All the viscera of the head, of the chest, and the abdomen, are covered with a serous membrane, which also lines the sides of these cavities, so that the viscera are not in contact with the sides, or with the adjoining viscera, except by the intermediation of this same membrane; and as its surface is very smooth, the viscera can easily change their relation with each other, and with the sides.

The principal circumstance which keeps up the polish of their surface is the exhalation of which they are the seat; a very thin fluid constantly passes out of every point of the membrane, and mixing with that of the adjoining parts, forms with it a humid layer that favours the frictions of the organs.

It appears that this facility of sliding upon each other is very favourable to the action of the organs, for as soon as they are deprived of it by any malady of the serous membrane, their functions are disordered, and they sometimes cease entirely.

In the state of health, the fluid secreted by the serous membranes appears to be the serum of the blood, a certain quantity of albumen excepted.

Serous Exhalation of the Cellular Tissue.

Exhalation of the cellular tissue

The tissue which is called *cellular* is generally distributed through the animal economy; it is useful at once to separate and unite the different organs, and the parts of the organs. This tissue is every where formed of a great number of small thin plates, which crossing in a thousand different ways form a sort of felt. The size and arrangement of the plates vary according to the different parts of the body. In one place they are larger, thicker, and constitute large cells; in another, they are very narrow and thin, and form extremely small cells; in some points the tissue is capable of extension; in others it is little susceptible of it, and presents a considerable resistance. But whatever is the disposition of the cellular tissue, its plates, by their two surfaces, exhale a fluid which has the greatest analogy with that of the serous membranes, and which appears to have the same uses; these are to render the frictions of the plates easy upon each other, and therefore to favour the reciprocal motions of the organs, and even the relative changes of the different parts of which they are composed.

Fatty Exhalation of the Cellular Tissue.

Independently of the serosity, a fluid is found in many parts of the cellular tissue of a very different nature, which is the fat. Fatty cells.

Under the relation of the presence of the fat, the cellular tissue may be divided into three sorts; that which contains it always, that which contains it sometimes, and that which never contains it. The orbit, the sole of the foot, the pulp of the fingers, that of the toes, always present fat; the subcutaneous cellular tissue, and that which covers the heart, the kidneys, &c. present it often; lastly, that of the scrotum, of the eyelids, of the interior of the skull, never contain it.

The fat is contained in distinct cells that never communicate with the adjoining ones; it has been supposed, from this circumstance, that the tissue that contains, and that forms the fat, was not the same as that by which the serosity is formed; but as these fatty cells have never been shown, except when full of fat, this anatomical distinction seems doubtful. The size, the form, the disposition of these cells, are not less variable than the quantity of fat which they contain. In some individuals scarcely a few ounces exist, whilst in others there are several hundred pounds.

According to the last researches of M. Chevreul, the human fat is almost always of a yellow colour. It is without odour; it begins to congeal from 89 to 66 degrees F. It is composed of two parts, the one fluid, the other concrete, which are themselves compounded, but in different proportions, of two new proximate principles discovered by M. Chevreul, *élaïn, stearin.*

Uses of the fat.

The fat appears to be useful in the animal economy principally by its physical properties; it forms a sort of elastic cushion in the orbit upon which the eye moves with facility; in the soles of the feet, and in the hips, it forms a sort of layer, which renders the pressure exerted by the body upon the skin and other soft parts less severe; its presence beneath the skin concurs in rounding the outlines, in diminishing the bony and muscular projections, and in beautifying the form; and as all fat bodies are bad conductors of caloric, it contributes to the preservation of that of the body. Full persons in general suffer little in winter by the cold.

Age, and the various modes of life, have much influence upon the development of this fluid; very young children are generally fat. Fat is rarely abundant in the young man; but the quantity of it increases much towards the age of thirty years, particularly if the nourishment is succulent and the life sedentary; the abdomen projects, the hips increase in size, as well as the breasts in women. The fat becomes more yellow in proportion as the age is more advanced.

Synovial Exhalations.

Synovial exhalations.

Round the moveable articulations a thin membrane is found, which has much analogy with the serous membranes; but which, however, differs from them by having small reddish prolongations that contain numerous blood vessels: these are called *synovial fringes;* they are very visible in the great articulations of the limbs. It was long believed, and many anatomists still believe that the articular capsules, reflected upon *diarthrodial cartilages*, cover the surfaces by which they correspond; but I have recently ascertained that the membranes do not go beyond the circumference of the cartilages.

We have treated of the uses of the *synovia*, in speaking of the motions.

Internal Exhalation of the Eye.

The different humours of the eye are also formed by exhalation; they are each of them separately enveloped in a membrane that appears intended for exhalation and absorption. Exhalation of the eye.

The humours of the eye are, the aqueous humour, the formation of which is at present attributed to the ciliary processes; the vitreous humour, secreted by the hyaloid; the chrystalline, the black matter of the choroid, and that of the posterior surface of the iris.

The chemical composition of the aqueous humour of the chrystalline and of the vitreous humour has been explained at the article *Vision;* the black matter of the choroid and the iris has been analyzed by M. Berzelius: it is insoluble in water and the acids; the caustic alkalis dissolve it, and the acids precipitate it from this solution. It burns like a vegetable matter, and leaves ferruginous ashes.

We learn from experience that the aqueous and vitreous humours are renewed with rapidity, when pus or blood has been effused in the eye; it disappears in a few days, and the humours recover their transparency by degrees.

It does not appear that the matter of the chrystalline, or that of the choroid, are thus capable of reproduction, at least nothing seems to prove it.

Bloody Exhalations.

In all the exhalations of which we have spoken, it is only a part of the principle of the blood that passes out of the vessels; the blood itself appears to spread in several of the organs, and fill in them the sort of cellular tissue which forms their parenchyma; such are the cavernous bodies of the penis and of the clitoris, the urethra and the glans, the spleen, the mamilla, &c. The anatomical examination of these different tissues seems to show that they are habitually filled with venous blood, the quantity of which is variable according to different circumstances, particularly according to the state of action or of inaction of the organs. Bloody exhalations.

Many other interior exhalations exist also, amongst which I will notice those of the cavities of the internal ear, of the parenchyma, of the thymus, of the thyroid gland; that of the cavity of the *capsulæ suprarenales,* &c.: but the fluids formed in these different parts are scarcely understood; they have never been analyzed, and their uses are unknown.

Explanation of exhalation.

Physiologists have often endeavoured to account for the phenomenon of exhalation; each has given his explanation; some have admitted exhaling mouths; others lateral pores. Bichât has created particular vessels which he calls *exhalants*. I say *created*, for he himself owns that these vessels cannot be seen; and as the existence of these pores, of these mouths or *exhalants*, is not sufficient to explain the diversity of exhalations, particular sensibilities and motions are supposed to belong to them, by virtue of which they admit only the passage of a certain part of the blood, and prevent that of others. We know how little is to depend on in explanations of this sort.

What appears much more certain is, that the physical disposition of the small vessels has an influence upon the exhalation, as the following facts seem to establish.

Experiments upon the exhalations.

When, in the dead body, tepid water is injected into an artery that goes into a serous membrane, as soon as the current is established from the artery to the vein, a great number of small drops pass out of the membrane, and quickly evaporate. Has not this phenomenon much analogy with exhalation?

If we employ a solution of gelatine, coloured with vermilion, to inject a whole body, it frequently happens that the gelatine is deposited round the circumvolutions, and in the cerebral anfractuosities, without the colouring matter having escaped from the vessels; on the contrary, the whole injection spreads at the external and internal surface of the choroid. If linseed oil is used, coloured also by vermilion, the oil, deprived of the colouring matter, is often seen deposited in the great synovial capsule of articulations, whilst there is no transudation at the surface of the brain, nor in the interior of the eye.

External Exhalations.

These are composed entirely of the exhalations of the *mucous membranes*, and of that of the skin, or *cutaneous transpiration*.

Exhalation of the Mucous Membranes.

There are two mucous membranes; the one covers the surface of the eye, the lacrymal ducts, the nasal cavities, the sinuses, the middle ear, the mouth, all the intestinal canal, the excretory canals which terminate in it; lastly, the larynx, the trachea, and the bronchia.

The other mucous membrane covers the organs of generation and of the urinary apparatus.

Exhalation of the mucous membranes.

These two membranes are always lubricated by a fluid which they secrete, and that is called *mucus*. This fluid is transparent, glutinous, thready, and of a salt savour; it reddens paper of turnsol, contains a great deal of water, muriate of potass and soda, lactate of lime, of soda, and phosphate of lime. According to MM. Fourcroy and Vauquelin, the mucus is the same in all the mucous membranes. On the contrary, M. Berzelius thinks it variable according to the points from which it is extracted. Many persons think that the mucus is exclusively formed by the follicles contained in the mucous membranes; but I have ascertained, by recent experiments, that it is formed in places where no follicles exist. I have also remarked that it is produced some time after death.

Of mucus.

The mucus forms a layer of greater or less thickness at the surface of the mucous membranes, and it is renewed with more or less rapidity; the water it contains evaporates under the name of *mucous exhalation;* it also protects these membranes against the action of the air, of the aliment, the different glandular fluids, &c.; it is, in fact, to these membranes nearly what the epidermis is to the skin. Independently of this general use, it has others that vary according to the parts of the mucous membranes. Thus, the mucus of the nose is favourable to the smell, that of the mouth gives facility to the taste, that of the stomach and the intestines assists in the digestion, that of the genital and urinary ducts serves in the generation and the secretion of the urine, &c.

A great part of the mucus is absorbed again by the membranes which secrete it; another part is carried outwards, either alone, as in blowing the nose, or spitting, or mixed with the pulmonary transpiration, or else mixed with the excremental matter, or the urine, &c.

Cutaneous Transpiration.

Insensible transpiration.

A transparent liquid, of an odour more or less strong, salt, acid, usually passes through the innumerable openings of the epidermis. This liquid is generally evaporated as soon as it is in contact with the air, and at other times it flows upon the surface of the skin. In the first case it is imperceptible, and bears the name of *insensible transpiration;* in the second it is called *sweat.*

Whatever form it takes, the liquid that escapes from the skin is composed, according to M. Thénard, of a great deal of water, a small quantity of acetic acid, of muriate of soda and potash, a small quantity of earthy phosphate, an atom of oxid of iron, and a trace of animal matter. M. Berzelius considers the acid of sweat not the same as the acetic acid, but like the lactic acid of Schèel. The skin exhales, besides, an oily matter, and some carbonic acid.

Experiments upon cutaneous transpiration.

Many experiments have been made to determine the quantity of transpiration which is formed in a given time, and the variations that this quantity undergoes according to circumstances. The first attempts are due to Sanctorius, who, during thirty years, weighed, every day, with extreme care, and an indefatigable patience, his food and his drink, his solid and liquid excretions, and even himself. Sanctorius, in spite of his zeal and perseverance, arrived at results that were not very exact. Since his time, several philosophers and physicians have been employed on the same subject with more success; but the most remarkable labour in this way is that of Lavoisier and Seguin. These philosophers were the first who distinguished the loss that takes place by pulmonary transpiration from that of the skin. M. Seguin shut himself up in a bag of *gummed silk,* tied above his head, and presenting an opening, the edges of which were fixed round his mouth by a mixture of turpentine and pitch. In this manner, only the humour of the pulmonary transpiration passed into the air. In order to know the quantity, it was sufficient to weigh himself, with the bag, at the beginning and end of the experiment, in a very fine balance. By repeating the experiment out of the bag, he determined the whole quantity of humour transpired; so that, by deducting from this the quantity that he knew had passed out from the lungs, he had the quantity of humour exhaled by the skin. Besides, he took into account the food that he had used, his excretions solid and liquid, and generally all the causes that could have any influence upon the transpiration. By following this plan, the results of MM. Lavoisier and Seguin are these:*—

* Annales de Chèmie, tom. xc. p. 14.

1st, The greatest quantity of insensible transpiration (the pulmonary included) is 25.6 grains troy per minute; consequently, 3 ounces, 1 drachm, 36 grains, per hour; and 6 pounds, 4 ounces, 6 drachms, 24 grains, in 24 hours.

2d, The least considerable loss is 8.8 grains per minute; consequently, 2 pounds, 2 ounces, 3 drachms, in 24 hours.

3d, It is during the digestion that the loss of weight occasioned by insensible transpiration is at its minimum.

4th, The transpiration is at its maximum immediately after dinner.

5th, The mean of the insensible transpiration is 14.4 grains per minute; in the mean 14.4 grains, 8.8 depend on cutaneous transpiration, and 5.6 upon the pulmonary.

6th, The cutaneous transpiration alone varies during and after repasts.

7th, Whatever quantity of food is taken, or whatever are the variations of the atmosphere, the same individual, after having augmented in weight by all the food that he has taken, returns, in 24 hours, to the same weight nearly that he was the day before, provided he is not growing, or has not eaten to excess.

It is much to be wished that this interesting labour had been continued, and that authors had not limited their studies to insensible transpiration, but had extended their observations to the sweat.

Of the sweat.

Whenever the humour of transpiration is not evaporated, as soon as it is in contact with the air, it appears at the surface of the skin in the form of a layer of liquid of variable thickness. Now, this effect may happen because the transpiration is too copious, or because of the diminution of the dissolvent force of the air. We perspire in an air hot and humid, by the influence of the two causes joined; we would perspire with more difficulty in an air of the same heat, but dry. Certain parts of the body transpire more copiously, and sweat with more facility than others; such are the hands and the feet, the arm-pits, the groins, the brow, &c. Generally the skin of these parts receives a greater proportional quantity of blood; and in some people, the arm-pit, the sole of the foot, and the intervals between the toes, do not come so easily in contact with the air.

The sweat does not appear to have every where the same composition; every one knows that its odour is variable according to the different parts of the body; it is the same with its acidity, which appears much stronger in the arm-pits and the feet than elsewhere.

Uses of the cutaneous transpiration.

The cutaneous transpiration has numerous uses in the animal economy, keeps up the suppleness of the epidermis, and thus favours the exercise of the tact and the touch. It is by evaporation along with that of the lungs, the principal means of cooling, by which the body maintains itself within certain limits of temperature; also its expulsion from the economy appears very important, for every time that it is diminished or suspended derangements of more or less consequence follow, and many diseases are not arrested until a considerable quantity of sweat is expelled.

Follicular Secretions.

Follicular Secretions.

The follicles are small hollow organs, lodged in the skin or mucous membranes, and which on that account are divided into *mucous* and *cutaneous.*

The follicles are, besides, divided into simple and compound.

Mucous follicular Secretions.

Mucous follicular secretions.

The simple mucous follicles are seen upon nearly the whole extent of the mucous membranes, where they are more or less abundant; however, there are points of considerable extent of these membranes where they are not seen.

The bodies that bear the name of *fungous papillæ* of the tongue, the amygdalæ, the glands of the cardia, the prostate &c., are considered by anatomists as collections of simple follicles: perhaps this opinion is not sufficiently supported.

The fluid that they secrete is little known; it appears analogous to the mucus and to have the same uses.

Cutaneous follicular Secretions.

Cutaneous follicular secretions.

In almost all the points of the skin little openings exist, which are the orifices of small hollow organs, with membranous sides, generally filled with an albuminous and fatty matter, the consistence, the colour, the odour, and even the savour of which are variable according to the different parts of the body, and which is continually spread upon the surface of the skin.

These small organs are called the follicles of the skin; one of them at least exists at the base of each hair, and generally the hairs traverse the cavity of a follicle in their direction outwards.

The follicles form that mucous and fatty matter which is seen upon the skin of the cranium and on that of the pavilion of the ear; the follicles also secrete the *cerumen* in the auditory canal; that whitish matter, of considerable consistence, that is pressed out of the skin of the face in the form of small worms, is also contained in follicles; it is the same matter, which, by its surface being in contact with the air, becomes black, and produces the numerous spots that are seen upon some person's faces, particularly on the sides of the nose and cheeks.

The follicles also appear to secrete that odorous, whitish matter, which is always renewed at the external surface of the genital parts.

By spreading on the surface of the epidermis, of the hair of the head, of the skin, &c., the matter of the follicles supports the suppleness and elasticity of those parts, renders their surface smooth and polished, favours their frictions upon one another: on account of its unctuous nature, it renders them less penetrable by humidity, &c.

Glandular Secretions.

The name of gland is given to a secreting organ which sheds the fluid that it forms upon the surface of a mucous membrane, or of the skin, by one or more excretory canals. Glandular secretions.

The number of glands is considerable; the action of each bears the name of glandular secretion. There are six secretions of this sort, that of the tears, of the saliva, of the bile, of the pancreatic fluid, of the urine, of the semen, and lastly, that of the milk; we may add the action of the mucous glands, and of the glands of Cowper.

Secretion of Tears.

The gland that forms the tears is very small; it is situated in the orbit of the eye above and a little outward; it is composed of small grains, united by cellular tissues; its excretory canals, small and numerous, open behind the external angle of the upper eyelid: it receives a small artery, a branch of the ophthalmic, and a nerve, a division of the fifth pair. Secretion of the tears.

Nature of the tears. In a state of health the tears are in small quantity; the liquid that forms them is limpid, without odour, of a salt savour. MM. Fourcroy and Vauquelin, who analyzed it, found it composed of much water, of some centesimals of mucus, muriate and phosphate of soda, and a little pure soda and lime. What are called *tears*, are not, however, the fluid secreted entirely by the lacrymal gland; it is a mixture of this fluid with the matter secreted by the conjunctiva, and probably with that of the glands of Meibomius.

Uses of the tears. The tears form a layer before the conjunctiva of the eye, and defend it from the contact of air; they facilitate the frictions of the eyelids upon the eye, favour the expulsion of foreign bodies, and prevent the action of irritating bodies upon the conjunctiva; in this case the quantity rapidly augments. They are also a means of expressing the passions: the tears flow from vexation, pain, joy and pleasure; the nervous system has therefore a particular influence upon their secretion. This influence probably takes place by means of the nerve that the fifth pair of cerebral nerves sends to the lacrymal gland.—See Article *Vision*.

Secretion of the Saliva.

Secretion of the saliva. The salivary glands are, 1st, the two parotids, situated before the ear and behind the neck, and the branch of the jaw; 2nd, the submaxillary, situated below and on the front of the body of this bone; 3d, lastly, the sublinguals, placed immediately below the tongue: the parotids and the submaxillaries have only one excretory canal; the sublinguals have several. All these glands are formed by the union of the granulations of different forms and dimensions; they receive a considerable quantity of arteries relatively to their mass; several nerves are distributed to them which proceed from the brain or the spinal marrow.

The saliva which these glands secrete flows constantly into the mouth, and occupies the inferior part of it; it is at first placed between the anterior and lateral part of the tongue and the jaw, and when the space is filled, it passes into the space between the lower lip, the cheek, and the external side of the jaw; being thus deposited in the mouth it mixes with the fluids secreted by the membranes and the mucous follicles.

The liquid which proceeds from a salivary gland has never been directly analyzed; it is always the fluid found in the mouth, and which is in reality almost composed of saliva. It has been found limpid, viscous, without colour or odour, of an agreeable savour, a little heavier than water. According to M. Berzelius, it is thus formed: water, 992.9; a particular animal matter, 2.9; mucus, 1.4; muriate of potass and soda, 0.7; tartrate of soda and animal matter, 0.9; soda, 0.2. This composition of the saliva is probably variable, for, in certain circumstances, it is sensibly acid. Chemical composition of the saliva.

The saliva is one of the most useful digestive fluids; it is favourable to the maceration and division of the food; it assists their deglutition and transformation into chyme; it also renders more easy the motions of the tongue in speech and in singing. The greatest part of the fluid is carried into the stomach by the motions of deglutition; another part must evaporate and go out of the mouth with the expired air. Uses of the saliva.

Secretion of the Pancreatic Juice.

The pancreas is situated transversely in the abdomen, behind the stomach; it has an excretory canal, which opens into the duodenum beside that of the liver: the granulous structure of this gland has made it be considered a salivary gland; but it is different from them by the smallness of the arteries that it receives, and by not appearing to receive any cerebral nerve. Secretion of the pancreatic juice.

De Graaf, a Dutch anatomist, formerly gave a process for collecting pancreatic juice; it consists in introducing into the excretory canal of the pancreas, in its intestinal extremity, a small quill, to which is attached a small bottle, placed under the belly of the animal. I have several times tried this process, but I think it impracticable. The quill, or any other tube, tears the internal mucous membrane of the canal, the blood flows, and the tube is very soon stopped. I employ a much simpler mode: I lay bare the orifice of the canal in a dog, I wipe the surrounding mucous membrane with a very fine cloth, and I wait until a drop of liquid passes out; as soon as it appears, I suck it up with a *pipette*, an instrument used in chemistry. In this manner I have succeeded in collecting come drops of pancreatic juice, but never enough to analyze it according Manner of obtaining pancreatic juice.

to rule. I have recognised in it a slightly yellow colour, a salt taste, no odour; I found that it was alkaline, and partly coagulable by heat.*

Properties of the pancreatic juice.

What I have been most struck with in endeavouring to procure pancreatic juice is, the smallness of the quantity which forms it; a drop scarcely passes out in half an hour, and I have sometimes waited longer for it. It does not flow more rapidly during digestion; but, on the contrary, it seems slower. I think it is generally more copious in very young animals.

It is impossible to explain the use of the pancreatic juice.

Secretion of the Bile.

Secretion of the bile.

The liver is the largest of all the glands; it is also distinguished by the singular circumstance among the secretory organs, that it is constantly traversed by a great quantity of venous blood, besides the arterial blood, which it receives as well as every other part. Its parenchyma does not resemble, in any respect, that of the other glands, and the fluid formed by it is not less different from that of the other glandular fluids.

The excretory canal of the liver goes to the duodenum; before entering it, it communicates with a small membranous bag, called *vesicula fellis*, and on this account, that it is almost always filled with bile.

Physical and chemical properties of the bile.

Few fluids are so compound, and so different from the blood, as the bile. Its colour is greenish, its taste very bitter; it is viscous, thready, sometimes limpid, and sometimes muddy. It contains water, albumen, a matter called resinous by some chemists, a yellow colouring principle, soda, and some salts, viz.—muriate, phosphate, and sulphate of soda, phosphate of lime, and oxid of iron. These properties belong to the bile contained in the gall bladder. That which goes out directly from the liver, called *hepatic bile*, has never been analyzed; it appears to be of a less deep colour, less viscous, and less bitter than the *cystic bile*. (90)

* In birds, which have two pancreases, their ducts have an almost perpetual peristaltic motion; the pancreatic juice is also much more abundant, and totally albuminous; at least, it hardens by heat, like albumen.

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(90) Professor Berzelius has lately shown that the curious proximate principle named *Picromel*, is not, as was formerly supposed, peculiar to the bile of oxen, but is found also in man.

Excretion of the bile.

The formation of the bile appears constant. In whatever circumstances an animal is placed, if the orifice of the *ductus choledochus* is laid bare, this liquid is seen to flow, drop by drop, at the surface of the intestine. The vesicle appears to fill more when the stomach is empty, and the abdominal pressure is less. It has always appeared to me more distended at this instant; but it does not completely empty itself by the distension of the stomach. Vomiting contributes most to the expulsion of the bile from it. I have often found it empty in animals that had died by the effect of an emetic poison.

Opinions upon the secretion of bile.

The liver receiving venous blood at the same time by the vena porta, and arterial blood by the hepatic artery, physiologists have been very eager to know which of the two it is that forms the bile. Several have said that the blood of the vena porta, having more carbon and hydrogen than that of the hepatic artery, is more proper for furnishing the elements of the bile. Bichât has successfully contested this opinion; he has shown, that the quantity of arterial blood which arrives at the liver is more in relation with the quantity of bile formed than that of the venous blood; that the volume of the hepatic canal is not in proportion with the vena porta; that the fat, a fluid much hydrogenated, is secreted by the arterial blood, &c.; he might have added, that there is nothing to prove that the blood of the vena porta has more analogy with the bile than the arterial blood. We shall take no part in this discussion; both opinions are equally destitute of proof. Besides, nothing repels the idea, that both sorts of blood serve in the secretion. This seems even to be indicated by anatomy; for injections show that all the vessels of the liver, arterial, venous, lymphatic, and excretory, communicate with each other.

The bile contributes very usefully in digestion, but the manner is unknown. In our present ignorance relative to the causes of diseases, we attribute noxious properties to the bile, which it is probably far from possessing.

Secretion of the Urine.

Secretion of the urine

The secretion we are now going to describe is different, in several respects, from the preceding. The liquid which results from it is much more abundant than that of any other gland; in place of serving in any internal uses it is expelled; its retention would be attended by the most dangerous consequences. We are advertised of the necessity of its expulsion by a particular feeling, which, like the instinctive phenomena of this sort, become very painful if they are not quickly attended to.

Few of the apparatus of secretion are so complicated as that of the urine; it is composed of the two kidneys, of the *calices*, of the pelvis, of the *ureters*, of the bladder and the *urethra;* besides, the abdominal muscles contribute to the action of these different parts, amongst which the kidneys alone form urine; the others serve in its transportation and expulsion.

Of the kidneys.

Situated in the abdomen, upon the sides of the vertebral column, before the last false ribs and the *quadratus lumborum*, the kidneys are of small volume relatively to the quantity of fluid they secrete. They are generally surrounded with a great deal of fat; their parenchyma is composed of two substances; the one exterior, vascular, or *cortical;* the other called *tubular*, disposed in a certain number of cones, the base of which corresponds to the surface of the organ, and their summits unite in the membranous cavity called *pelvis*. Its cones appear formed by a great number of small hollow fibres, which are excretory canals of a particular kind, and which are generally filled with urine.

Quantity of blood which goes to the kidney.

In respect of its volume, no organ receives so much blood as the kidney. The artery which is directed there is large, short, and proceeds immediately from the aorta; it has easy communications with the veins and the tubulous substance, as may be easily ascertained by means of the most coarse injections, which, being thrown into the renal artery pass into the veins and into the pelvis, after having filled the cortical substance.

Excretory canal of the kidneys.

The filaments of the great sympathetic alone are distributed to the kidneys. The *calices*, pelvis, and ureter, form together a canal which commences in the kidneys, where it embraces the top of the mamillary processes, and placed at the sides of the vertebral column, it goes in the bottom of the pelvis to the bladder, where it terminates.

Of the bladder and the urethra.

This last organ is an extensible and contractile sac, intended to hold the fluid secreted by the kidneys, and which communicates with the interior by a canal of considerable length in man, but very short in woman, called *urethra*.

The posterior extremity of the urethra is, only in man, surrounded by the *prostate* gland, which is considered by certain anatomists as a collection of mucous follicles. Two small glands placed before the anus pour a particular fluid into this canal. Two muscles which descend from the pubis towards the rectum, pass upon the sides of the part of the bladder which ends in the urethra, approach one another behind, and form a small arc which surrounds the neck of the bladder, and carries it more or less upwards.

If the pelvis is cut open in a living animal, the urine is seen to pass out slowly by the summits of the excretory cones. This liquid is deposited in the cavity of the *calices*, then enters that of the pelvis, and then by little and little it enters into the *ureter*, through the whole length of which it passes. It thus arrives at the bladder, into which it penetrates by a constant exsudation, as is easy to be observed in persons affected with the vicious conformation called *retroversion of the bladder*, in which the internal surface of this organ is accessible to the view. Passage of the urine from the kidneys.

A slight compression upon the uriniferous cones makes the urine pass out in considerable quantity; but instead of being limpid, as when it passes out naturally, it is muddy and thick. It appears then to be filtered by the hollow fibres of the tubular substance.

Neither the *pelvis* nor the *ureter* being contractile, probably the power which produces the motion of the urine is, on one hand, that by which it is poured into the *pelvis*,* and on the other the pressure of the abdominal muscles, to which may be added, when we stand upright, the weight of the liquid.

Under the influence of these causes the urine passes into the bladder, and slowly distends this organ, sometimes to a considerable degree; this accumulation being permitted by the extensibility of different organs.†

* Since it is proved that the heart and the contraction of the arteries have a marked influence upon the course of the blood in the capillaries and in the veins, why should not these same causes act on the motion of the fluids in separate excretory canals?

† Physiologists have long compared the introduction of the urine into the bladder, to that of a liquid into a cavity with resisting sides, by a narrow, vertical, and inflexible canal; but the comparison is not just. In the supposed canal the liquid flows, and continually presses the liquid contained in the canal that receives it. The urine does not flow into the *ureter*;

Causes that produce the accumulation of urine in the bladder.

How does the urine accumulate in the bladder? Why does it not flow immediately by the urethra? and why does it not flow back into the ureter? The answer is easy for the ureters: these conduits pass a considerable distance into the sides of the bladder. In proportion as the urine distends this organ, it flattens the ureters, and shuts them so much more firmly as it is more abundant. This takes place in the dead body as well as in the living; also, a liquid, or even air, injected into the bladder, by the urethra, never enters the ureters. It is, then, by a mechanism analogous to that of certain valves, that the urine does not return towards the kidneys.

It is not so easy to explain why the urine does not flow by the urethra; several causes appear to contribute to this. The sides of this canal, particularly towards the bladder, have a continual tendency to contract, and to lessen the cavity; but this cause alone would be insufficient to resist the efforts of the urine to escape, when the bladder is full. In the dead body, in which the canal contracts nearly in the same manner, it has but a very weak resistance, and does not prevent the passage of the liquid outwards, though the bladder may be very little compressed.

The angle of the bladder with the urethra, when it is strongly distended, may also present an obstacle to the passage of the urine; but what I believe the principal cause is the contraction of the elevating muscles of the anus, which, either by the disposition to contraction of the muscular fibres, or by their contraction under the influence of the brain, press the urethra upwards, compress its sides with more or less force against each other, and thus shut its posterior orifice.

it *sweats* into it, and in this respect its influence upon the distension of the bladder cannot be compared to that which the weight of a liquid would produce. The pressure of the abdomen must have a great part in the dilatation of the bladder by the urine. If the bladder and the ureters are equally pressed, this is sufficient for the introduction of the urine into the bladder. Supposing the pressure equal in all the points of the abdomen, if the surface of the pelvis and of the ureter is higher than that of the bladder, the urine ought to enter easily into it; but the abdominal pressure appears to be much less in the pelvis than in the abdomen properly so called; so that it is easy to understand how the urine passes from the ureters into the bladder.

Nevertheless the distension of the bladder by the access of the urine is limited; when the organ contains two pints or more of urine the distension stops, and the ureters dilate in their turn, from the inferior towards the superior portion.

Excretion of Urine.

As soon as there is a certain quantity of urine in the bladder, we feel an inclination to discharge it. The mechanism of this expulsion deserves particular attention, and has not always been well understood.

If the urine is not always expelled, this ought not to be attributed to the want of contraction in the bladder, for this organ always tends to contract; but, by the influence of the causes that we have noticed, the internal orifice of the urethra resists with a force that the contraction of the bladder cannot surmount. The will produces this expulsion—1st, by adding the contraction of the abdominal muscles to that of the bladder; 2dly, by relaxing the *levatores ani*, which shut the urethra. The resistance of this canal being once overcome, the contraction of the bladder is sufficient for the complete expulsion of the urine it contained: but the action of the abdominal muscles may be added, and then the urine passes out with much greater force. We may also stop the flowing of the urine all at once, by contracting the levators of the anus. Expulsion of the urine.

The contraction of the bladder is not voluntary, though, by acting on the abdominal muscles, and the levators of the anus, we may cause it to contract when we choose.

The urine that remains in the urethra after the bladder is empty, is expelled by the contraction of the muscles of the perineum, and particularly by that of the *acceleratores urinæ*.

Though the quantity of urine is very copious, and though it contains several proximate principles which are not found in the blood, and consequently a chemical action takes place in the kidneys, the secretion of the urine is nevertheless very rapid. Action of the reins.

In a state of health, the colour of the urine is yellow; its taste is salt, and a little bitter; its odour is peculiar to itself. It is composed of water, of mucus, which probably proceeds from the mucous membrane of the urinary ducts, of another animal matter, of uric acid, of phosphoric acid, of lactic acid, of muriate of soda and ammonia, phosphate of soda, of ammonia, of lime, of magnesia, of sulphate of potass, of lactate of ammonia, and of silex. Physical properties of urine. Chemical properties of urine.

The physical properties of urine are subject to great variations. If rhubarb or madder has been used, it becomes of a deep yellow, or blood red; if one has breathed Modifications of the physical or chemical properties of urine.

an air charged with vapours of oil of turpentine, or if a little rosin has been swallowed, it takes a violet odour: the disagreeable odour that it takes by the use of asparagus, is well known.

Its chemical composition is not less variable. The more use that is made of watery beverages, the more considerable the total quantity and proportion of water become; if one drinks little, the contrary happens.

The uric acid becomes more abundant when the regimen is very substantial, and the exercise trifling; this acid diminishes, and may even disappear altogether, by the constant and exclusive use of unazotised food, such as sugar, gum, butter, oil, &c. Certain salts, carried into the stomach, even in small quantity, are found in a short time in the urine.

The extreme rapidity with which this translation takes place, has made it be supposed there is a direct communication between the stomach and the bladder: even now there are considerable numbers of partisans in favour of this opinion.

It is not yet long since a direct canal from the stomach to the bladder was supposed to exist, but this passage has no existence; others have supposed, without giving any proof, that the passage took place by the cellular tissue, by the anastomoses of the lymphatic vessels, &c.

Passage of drinks from the stomach to the bladder.

Darwin having given to a friend several grains of nitrate of potass, in half an hour he let blood of him and collected his urine: the salt was found in the urine, but not in the blood. Mr. Brand made similar observations with prussiate of potass; he concluded from it that the circulation is not the only means of communication between the stomach and the urinary organs, but without giving any explanation of the existing means. Sir Everard Home is also of this opinion.

Experiments upon the secretion of urine.

I have made experiments in order to clear up this important question, and I have found, 1st, that whenever prussiate of potass is injected into the veins, or absorbed in the intestinal canal, or by a serous membrane, it very soon passes into the bladder, where it is easily recognised amongst the urine; 2dly, that if the quantity of prussiate injected is considerable, the tests can discover it in the blood; but if the quantity is small, its presence cannot be recognised by the usual means; 3dly, that the same result takes place by mixing prussiate and blood together in a vessel; 4thly, that the same salt is recognised in all proportions in the urine. It is not extraordinary, then, that Darwin and Mr. Brand did not find in the blood the substance that they distinctly perceived in the urine.

With regard to the organs that transport the liquids of the stomach and intestines into the circulating system, it is evident, according to what we have said, in speaking of the chyliferous vessels, and the absorption of the veins, that these liquids are directly absorbed by the veins, and transported by them to the liver and the heart; so that the direction which these liquids follow, in order to reach the veins, is much shorter than is generally admitted, viz. by the lymphatic vessels, the mesenteric glands, and the thoracic duct.

Explanation of glandular secretions.

In explaining the glandular secretions, physiologists have given full scope to their imagination. (91) The glands have been successively considered as sieves, filters, as a focus of fermentation. Bordeu, and, more recently, Bichât, have attributed a peculiar motion and sensibility to their particles, by which they choose, in the blood which traverses them, the particles that are fit to enter into the fluids that they secrete. Atmospheres and compartments have been allotted to them; they have been supposed susceptible of erection, of sleep, &c. Notwithstanding the efforts of many learned men, the truth is, that what passes in a gland when it acts is entirely unknown. Chemical phenomena necessarily take place.

Several secreted fluids are acid, whilst the blood is alkaline; the most of them contain proximate principles which do not exist in the blood, and which are formed in the glands; but the particular mode of these combinations is unknown.

We must not, however, confound amongst these suppo-

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(91) Many theories have been devised to explain secretion. As,

1. That fluids are separated by a sort of infiltration.
2. ———— by the contributions of the vasa vasorum.
3. ———— by chemical attraction.
4. ———— by electricity.
5. ———— by galvanism.
6. ———— by inexplicable laws.
7. ———— by fermentation.
8. ———— by gravitation.
9. ———— by corresponding momentum of the fluids, and dilatability of the last tubes.

sitions upon the action of the glands, an ingenious conjecture of Doctor Wollaston. This learned man supposes that very weak electricity may have a marked influence upon the secretions: he rests his opinion upon a curious experiment, of which we will here give an account.

Experiments upon the glandular secretions.

Doctor Wollaston took a glass tube, two inches long, and three quarters of an inch diameter; he closed one of its extremities with a bit of bladder. He poured a little water into the tube, with $\frac{1}{240}$ part of its weight of muriate of soda; he wet the bladder on the outside, and placed it on a piece of silver; he then bent a zinc wire, so that one of its ends touched the silver, and the other entered the tube the length of an inch. In the same instant the external face of the bladder gave indications of the presence of pure soda; so that, under the influence of this very weak electricity, there was a decomposition of muriate of soda, and a passage of the soda, separated from the acid, through the bladder. Dr. Wollaston thinks it is not impossible that something analogous may happen in the secretions; but, before admitting this idea, many other proofs are necessary.

Several organs, such as the thyroid and thymus bodies, the spleen, the supra-renal capsules, have been called glands by many anatomists: Professor Chaussier has substituted for this denomination that of the *glandiform ganglions.* The use of these parts is entirely unknown. As they are generally more voluminous in the fœtus, they are supposed to have important functions, but there exists no proof of it. Works of Physiology contain a great many hypotheses intended to explain their functions.

OF NUTRITION.

We know that the blood supplies all the secretions, internal and external; that it is renewed by general absorption, and by that of the chyle and the drinks: it now remains for us to study what takes place in the parenchyma of the organs and the tissues during the continuation of life, namely, *nutrition* properly so called.

From the state of the embryo to the most advanced old age, the weight and volume of the body are almost continually changing; the different organs and tissues present infinite variations in their consistence, colour, elasticity, and sometimes their chemical composition. The volume of the organs augments when they are often in action; on the contrary, their size diminishes when they remain long at rest. By the influence of one or other of these causes, their chemical and physical properties present remarkable variations. Many diseases often produce, in a very short time, remarkable changes in the exterior conformation, and in the structure of a great number of organs.

If madder is mixed with the food of an animal, in fifteen or twenty days the bones present a red tint, which disappears when the use of it is left off.

There exists, then, in the organs, an insensible motion of the particles which produce all these modifications. It is this interior motion, unknown in its nature, that is called *nutrition*, or *nutritive action*.

Suppositions with regard to nutrition.

This phenomenon, which the observing spirit of the ancients had not permitted to escape, was to them the object of many ingenious suppositions that are still admitted.—For example, it is said that, by means of the nutritive action, the whole body is renewed, so that, at a certain period, it does not possess a single particle of the matter that composed it formerly. Limits have even been assigned to this total renewal: some have fixed the period of three years; others think it is not complete till seven: but there is nothing to give probability to these conjectures; on the contrary, certain well proved facts seem to render them of no avail.

It is well known that soldiers, sailors, and several savage people colour their skins with substances which they introduce into the tissue of this membrane itself: the figures thus traced preserve their form and colour during their lives, should no particular circumstances occur. How can this phenomenon agree with the renewal of the skin according to these authors?*

In resting on the suppositions of which we have spoken, it is admitted, in the metaphorical language now used in

* The recent use of nitrate of silver internally, in the cure of epilepsy, furnishes a new proof of this kind. After some months' use of this substance, some sick persons have had their skin coloured of a greyish blue, probably by a deposition of the salt in the tissue of this membrane, where it is immediately in contact with the air. Several individuals have been in this state for some years without the tint becoming weaker; whilst in others it has diminished by degrees, and disappeared in two or three years.

physiology, that the atoms of the organs can only serve for a certain period in their composition; that in time they *wear*, and become at last improper to enter into their composition; and that they are then absorbed and replaced by new atoms proceeding from the food.

It is added, that the animal matters of which our excretions are composed are the *detritus* of the organs, and that they are principally composed of atoms that can no longer serve in their composition, &c., &c.

Instead of discussing these hypotheses, we shall mention a few facts from which we have some idea of the nutritive movement.

Remarks upon nutrition.

A. In respect to the rapidity with which the organs change their physical and chemical properties by sickness or age, it appears that nutrition is more or less rapid according to the tissues. The glands, the muscles, the skin, &c., change their volume, colour, consistence, with great quickness; the tendons, the fibrous membranes, the bones, the cartilages, appear to have a much slower nutrition, for their physical properties change but slowly by the effect of age and disease.

B. If we consider the quantity of food consumed proportionally to the weight of the body, the nutritive movement seems more rapid in infancy and youth, than in the adult and in old age; it is accelerated by the repeated action of the organs, and retarded by repose. Indeed, children and young people consume more food than adults and old people: these last can preserve all their faculties by the use of a very small quantity of food. All the exercises of the body, hard labour, require necessarily a greater quantity, or more nutritive food; on the contrary, perfect repose permits of longer abstinence.

C. The blood appears to contain most of the principles necessary to the nutrition of the organs; the fibrine, the albumen, the fat, the salts, &c., that enter into the composition of the tissues, are found in the blood. They appear to be deposited in their parenchyma at the instant when the blood traverses them; the manner in which this deposit takes place is entirely unknown. There is an evident relation between the activity of the nutrition of an organ and the quantity of blood it receives. The tissues that have a rapid nutrition have larger arteries; when the action of an organ has determined an acceleration of its nutrition, the arteries increase in size.

Many proximate principles that enter into the composition of the organs are not found in the blood: as osmazome, the cerebral matter, gelatine, &c. They are, therefore, formed from other principles in the parenchyma of the organs, in some chemical but unknown manner.

D. Since chemical analysis has made known the nature of the different tissues of the animal economy, they have been all found to contain a considerable portion of azote. Our food being also partly composed of this simple body, the azote of our organs likewise probably comes from them; but several eminent authors think that it is derived from respiration; others believe that it is formed by the influence of life solely. Both parties insist particularly upon the example of the herbivorous animals, which are supported exclusively upon non-azotised matter; upon the history of certain people that live entirely upon rice and maize; upon that of negroes who can live a long time without eating any thing but sugar; lastly, upon what is related of *caravans*, which, in traversing the deserts, have for a long time had only gum in place of every sort of food. Were it indeed proved by these facts, that men can live a long time without azotised food, it would be necessary to acknowledge that azote has an origin different from the food; but the facts cited by no means prove this. In fact, almost all the vegetables upon which man and the animals feed contain more or less azote; for example, the impure sugar that the negroes eat presents a considerable proportion of it; and with regard to the people, as they say, who feed upon rice or maize, it is well known that they add milk or cheese: now *caséin* is the most azotised of all the nutritive proximate principles.

Remarks upon nutrition.

I have thought that we might acquire some exact notions on this subject, by submitting animals, during a necessary time, to the use of food, of which the chemical composition should be known.

Dogs are very proper for these experiments; they live, like man, equally well upon vegetable and animal substances.

It is well known that a dog can live a long time upon bread alone; but by thus feeding it nothing can be concluded relative to the production of azote in the animal economy, for the gluten that the bread contains is very full of azote. To obtain a satisfactory result, it must be necessary to feed one of these animals upon a nutritive substance that contains no azote.

Experiments upon nutrition.

For this purpose, I took a small dog of three years old, fat, and in good health, and put it to feed upon sugar alone, and gave it distilled water to drink: it had as much as it chose of both.

It appeared very well in this way of living the first seven or eight days; it was brisk, active, eat eagerly, and drank in its usual manner. It began to get thin the second week, though it had always a good appetite, and took about six or eight ounces of sugar in twenty-four hours. Its *alvine* excretions were neither frequent nor copious; that of the urine was very abundant.

In the third week its leanness increased, its strength diminished, the animal lost its liveliness, and its appetite was much lessened. At this period, there was developed upon one eye, and then on the other, a small ulceration on the centre of the transparent cornea; it increased very quickly, and in a few days it was more than a line in diameter; its depth increased in the same proportion; the cornea was very soon entirely perforated, and the humours of the eye ran out. This singular phenomenon was accompanied with an abundant secretion of the glands of the eye-lids.

It, however, became weaker and weaker, and lost its strength; and though the animal eat from three to four ounces of sugar per day, it became so weak that it could neither chew nor swallow; for the same reason every other motion was impossible. It expired the thirty-second day of the experiment. I opened it with every suitable precaution; I found a total want of fat; the muscles were reduced more than five-sixths of their ordinary size; the stomach and the intestines were also much diminished in volume, and strongly contracted.

The gall and urinary bladders were distended by their proper fluids. I begged M. Chevreul to examine them; he found in them nearly all the characters that belong to the urine and the bile of herbivorous animals; that is, that the urine, in place of being acid, as it is in carnivorous animals, was sensibly alkaline, and presented no trace of uric acid nor of phosphate. The bile contained a considerable portion of *picromel*, a character thought peculiar to the bile of the ox, and, in general, to that of herbivorous animals. The excrements, that were also examined by M. Chevreul, contained very little azote, whilst they generally present a great deal.

Such a result required to be proved by new experiments. I submitted a second dog to the same regimen as the former, that is, to sugar and distilled water. The phenomena that I observed were exactly similar to those I have just described; the only difference was, that the eyes did not begin to ulcerate until towards the twenty-fifth day, and the animal died before they had time to empty themselves, as had happened to the first dog, the subject of the first experiment: in other respects, there was the same emaciation, the same weakness, followed by death on the thirty-fourth day of the experiment; and, on opening the dead body, there was the same state of the muscles and of the abdominal viscera; and, above all, the same character of the excrements, the bile, and the urine.

A third experiment produced similar results, and thence I considered sugar incapable of supporting dogs of itself.

This want of the nutritive quality might be peculiar to sugar; I thought it important to ascertain if other substances not azotised, but generally considered as nourishing, produced similar effects.

I took two young and strong dogs, though of a small size; I gave them for their food very good olive oil and distilled water; they appeared to live well on it for about fifteen days; but they afterwards underwent the same series of accidents that I have mentioned in speaking of the animals that eat the sugar. They, however, suffered no ulceration of the cornea; they both died towards the thirty-sixth day of the experiment; with regard to the state of the organs, and that of the composition of the urine and the bile, they presented the same phenomena as the preceding.

Gum is another substance that contains no azote, but which is considered very nourishing. It might be supposed to act like sugar and oil, but this ought to be directly ascertained. In this view, I have fed several dogs with gum, and the phenomena I observed did not differ sensibly from those that I have mentioned.

I have lately repeated the experiment, by feeding a dog with butter, an animal substance free of azote: like the other animals, it was supported by this food very well at first; but, in about fifteen days, it began to grow lean, and lost its strength; it died the thirty-sixth day, although, on the thirty-fourth day, I gave it as much flesh as it would eat, a considerable quantity of which it took for two days. The right eye of this animal presented the ulceration of the cornea that I noticed in those that were fed on sugar. The opening of the body presented the same modifications of the bile and the urine.

Though the nature of the excrements of the different animals of which I have spoken gave indication that they digested the substances used by them, I wished to ascertain it in a more positive manner; on this account, after having given to dogs separately, oil, gum, or sugar, I opened them, and I found that these substances were each reduced to a particular chyme in the stomach, and that they afterwards furnished an abundant chyle: that which proceeds from oil is a distinct milky white; the chyle that proceeds from gum, or sugar, is transparent, opaline, and more watery than that of oil. It is, then, evident that, if these different substances are not nourishing, it cannot be attributed to the want of digestion.

These facts appear important in several respects; first, they make it very probable that the azote of the organs is produced by the food; they are very proper to clear up the causes and treatment of gout and gravel.*

Remarks upon nutrition.

E. A considerable number of tissues in the economy appear to have no nutrition, properly so called: as the epidermis, the nails, the hair,(93) the teeth, the colouring matter of the skin, and, perhaps, the cartilages.

These different parts are really secreted, by particular organs, as the teeth and the hair; or by parts which have other functions at the same time, as the nails and the epidermis. The most of the parts formed in this mode wear

* Persons seized with these diseases, are generally great eaters of flesh, of fish, of food prepared with milk, and other substances that contain a great deal of azote. The most frequent forms of the gravel, the *calculus* of the bladder, of the *arthritic tophus*, are formed by uric acid, a principle which contains a great deal of azote. By lessening, in the regimen, the quantity of azotised food, these diseases are prevented. (92)

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(92) The very valuable ideas advanced in this page, our author has afterwards developed more at large in his *Recherches Physiologiques et Medicales, sur les Causes, les Symptomes, et le Traitement de la Gravelle.* This work has deservedly met the approbation of the medical and learned world.

(93) See, on the hair, Dr. Fleming's Philosophy of Zoology.

by the friction of exterior bodies, and are constantly renewed; if they are entirely carried away, they are capable of reproduction. A very singular fact is, that they continue to grow several days after death: We have seen a similar phenomenon with regard to the mucus.

After this short account of the principal nutritive phenomena, we must examine a very important phenomenon which seems intimately connected with nutrition, but which has always very close relations with the respiration: I mean the production of heat in the body of man.

Of Animal Heat. (94)

An inert body which does not change its position, being placed amongst other bodies, very soon assumes the same temperature, on account of the tendency of caloric to an equilibrium. The body of man is very different: sur- Animal heat.

(94) *Animal heat.* Several suggestions which may appear rather novel in this article, are not to be attributed to our author, who merely copies them, on account of their singularity, from other authors. The originals, or references to them, may be found in Dr. Corden Thomson's excellent Essay on Human Heat, published as an inaugural dissertation here, in 1820. It is a work in which the best informed reader will find much to reward his inspection. The Dr. finds the general heat of the human body about 99° F., and this nearly, but not quite the same on all points of the surface: and he concludes, from many experiments, that age, sex, temperament, size, or way of life, make no difference whatever in the human temperature. Mr. Brodie, of London, has lately attempted to revive the doctrine of Caverhill (*On Heat*) respecting the origin of animal heat. "Nuper," says Haller in his *Auctarium*, *lib.* VI. 69, "Cl. Caverhill calorem ad nervorum actionem reduxit, eo potissimum experimento, quod læsa medulla spinali, calor insigniter depressus fuerit.—Cl. Caverhill unice videtur demonstrasse, vires vitales, læsa medulla spinali, debilitari, cumque his viribus calorem." After perusing this note with care, the reader will find little novelty either in Mr. Brodie's Theory or my reply to it; and I shall therefore briefly add, that inasmuch as the vascular and respiratory organs are capable of being affected by the nervous system, so much of the theory of Caverhill and Brodie is true, but no more; their experiments being merely capable of showing the extent of this influence. The animal heat, for aught proved by these experiments, may depend on a cause totally different from either vessels, lungs, or nerves: and on a theme concerning which our knowledge is so extremely slender, we cannot afford to give up the fine series of analogies which connected heat and respiration over the whole animal world, even in the early, rude, comparative anatomy of Democritus, (Aristotle *de respiratione*, 173.) for a bald resuscitation of a decayed hypothesis. Fresh be the laurels of the Caverhills and Crawfords, the Berards and Brodies! but plain truth must confess in her simplicity, that we should have known quite as much of animal heat without their interference. It is still a problem, to the solution of which, experiment will go much farther than the best hypothesis.

rounded by bodies hotter than itself, it preserves its inferior temperature as long as life continues; being surrounded with bodies of a lower temperature, it maintains its temperature more elevated. There are, then, in the animal economy, two different and distinct properties, the one of producing heat, the other of producing cold. We will examine these two properties;—let us first see how heat is produced.

Principal source of animal heat.

The respiration appears to be the principal, or at least the most evident source of animal heat. In fact, experience demonstrates that the heat of the blood increases nearly a degree in traversing the lungs; and as it is distributed to all the parts of the body from the lungs, it carries the heat every where into the organs; for we have also seen that the heat of the veins is less than that of the arteries.

This development of heat in the respiration appears, as we have already said, to proceed from the formation of carbonic acid, whether it takes place directly in the lungs, or happens afterwards in the arteries, or in the parenchyma of the organs. Some very good experiments of Lavoisier, and M. de Laplace, lead to this conclusion: they placed animals in a *calorimeter*, and compared the quantity of acid formed by the respiration, with the quantity of heat produced in a given time: except a very small proportion, the heat produced was that which would have been occasioned by the quantity of carbonic acid which was formed.

It has also been proved by the experiments of MM. Brodie, Thillaye and Legallois, that if the respiration of an animal is incommoded, either by putting it in a fatiguing position, or in making it respire artificially, its temperature lowers, and the quantity of carbonic acid that it forms becomes less. In diseases when the respiration is accelerated, the heat increases, except in particular circumstances. The respiration is then a focus in which caloric is developed.

In considering for an instant only this source of heat in the economy, we see that the caloric must be distributed to the different parts of the body in an unequal manner; those farthest from the heart, those that receive least blood, or which cool more rapidly, must generally be colder than those that are differently disposed.

This difference partly exists. The extremities are colder than the trunk; sometimes they present only 89°, or 91°

F., and often much less, while the cavity of the thorax is about 104° F.: but the extremities have a considerable surface relative to their mass; they are farther from the heart, and receive less blood than most of the organs of the trunk.

On account of the extent of their surface and distance from the heart, the feet and hands would probably have a temperature still lower than that which is peculiar to them, if these parts did not receive a greater proportional quantity of blood. The same disposition exists for all the exterior organs that have a very large surface, as the nose, the pavilion of the ear, &c.: their temperature is also higher than their surface and distance from the heart would seem to indicate.

Notwithstanding the providence of nature, those parts that have large surfaces lose their caloric with greater facility; and they are not only habitually colder than the others, but their temperature often becomes very low: the temperature of the feet and hands in winter is often nearly as low as 32° F. It is on this account we expose them so willingly to the heat of our fires.

Amongst other means that we instinctively employ to remedy or prevent coldness, are motion, walking, running, leaping, which accelerate the circulation; pressure, shocks upon the skin, which attract a great quantity of blood into the tissue of this membrane. Another equally effective means consists in diminishing the surface in contact with the bodies that deprive us of caloric. Thus we bend the different parts of the limbs upon each other, we apply them forcibly to the trunk when the exterior temperature is very low. Children and weak persons often take this position when in bed.* In this respect it would be very proper that young children should not be confined too much in their swathing clothes to prevent them from thus bending themselves.

Our clothes preserve the heat of our bodies; for the substances of which they are formed being bad conductors of caloric, they prevent that of the body from passing off.

According to what has been said, the combination of the oxygen of the air with the carbon of the blood is sufficient for the explanation of most of the phenomena presented by the production of animal heat; but there are

* See a memoir of M. Brès, on this subject, in the Journ. de Med. 1817.

several which, if real, could not be explained by this means. Authors worthy of credit have remarked that, in certain local diseases, the temperature of the diseased place rises several degrees above that of the blood, taken at the left auricle. If this is so, the continual renewal of the arterial blood is not sufficient to account for this increase of heat.

Second source of animal heat.

This second source of heat must belong to the nutritive phenomena which take place in the diseased part.

There is nothing forced in this supposition; for most of the chemical combinations produce elevations of temperature, and it cannot be doubted that both in the secretions and in the nutrition, combinations of this sort take place in the organs.

By means of these two sources of heat, life can be maintained though the external temperature is very low, as that of winter in the countries near the pole, which descends sometimes to—42° F. Generally such an excessive cold is not supported without great difficulty, and it often happens that the parts most easily cooled are mortified: many of the military suffered these accidents in the wars of Russia. Nevertheless, as we easily resist a temperature much lower than our own, it is evident that we are possessed of the faculty of producing heat to a great degree.

Means of resisting a strong heat.

The faculty of producing cold, or, in more exact terms, of resisting foreign heat which has a tendency to enter our organs, is more confined. In the torrid zone, it has happened that men have died suddenly when the temperature has approached 122° F.

But this property is not less real, though limited. MM. Banks, Blagden and Fordyce, having exposed themselves to a heat of nearly 260° F., they found that their bodies had preserved nearly their own temperature. More recent experiments of MM. Berger and Delaroche have shown that by this cause the heat of the body may rise several degrees: for this to take place it is only necessary that the surrounding temperature should be a little elevated. Having both placed themselves in a stove of 120°, their temperature rose nearly 6.8° F. M. Delaroche having remained sixteen minutes in a dry stove at 176°, his temperature rose 9° F.

Franklin, to whom the physical and moral sciences are indebted for many important discoveries, and a great many ingenious views, was the first who discovered the reason why the body thus resists such a strong heat. He showed that this effect was due to the evaporation of the cutaneous and pulmonary transpiration, and that in this respect the bodies of animals resemble the porous vases called *alcarrazas*. These vessels, which are used in hot countries, allow the water that they contain to sweat through them; their surface is always humid, and a rapid evaporation takes place which cools the liquid they contain.

Experiments upon animal heat.

In order to prove this important result, M. Delaroche placed animals in a hot atmosphere, that was so saturated with humidity that no evaporation could take place. These animals could not support a heat but a little greater than their own without perishing, and they became heated, because they had no longer the means of cooling themselves. Thus, there is no doubt that the cutaneous and pulmonary evaporation are the cause which enables man and animals to resist a strong heat. This explanation is also confirmed by the considerable loss of weight that the body suffers after having been exposed to a great heat.

According to these facts it is evident that the authors who have represented animal heat as fixed, have been very far from the truth. To judge exactly of it, it would be necessary to take into account the surrounding temperature and humidity; the degree of heat of different parts ought to be considered, and the temperature of one part ought not to be determined by that of another.

We have few correct observations upon the temperature proper to the body of man; the latest are due to MM. Edwards and Gentil. These authors observed that the most suitable place for judging of the heat of the body is the arm-pit. They noticed nearly 2½ degrees of difference between the heat of a young man and that of a young girl: the heat of her hand was a little less than 97¼°, that of the young man was 98.4°. The same persons observed great differences of heat in the different temperaments. There are also diurnal variations; the temperature may change about two or three degrees from morning to evening. In general it would be necessary to have new observations on this subject.

OF GENERATION.

The relative and nutritive functions establish the individual existence of man; but, like all animals, he is also called to exercise another very important function,—the creation of beings like himself, and thus to contribute to the continuation of the species.

By its intention, generation is already very different from the relative and nutritive functions; but it also differs from them in this, that the organs which co-operate in it, are not all found in the same individual; and by this diversity, is established the principal difference of the sexes.

Apparatus of Generation.

It is composed of the organs proper to the male, and of those peculiar to the female.

Genital Organs of the Male.

Male genital organs. These organs are the *testicles*, the *vesiculæ seminales*, the prostate gland, and the penis.

Testicles. The testicles are two in number. The cases related by authors, in which three and even four are said to have been seen, are very doubtful. Their form is ovoid, and their volume inconsiderable; their parenchyma consists of an infinite number of small convoluted vessels, which are denominated *seminiferous*, and are all directed towards one point of the surface, called the *head of the epididymis:* at this position they run together, anastomose, diminish in number, and terminate, by forming one cylindrical canal, which lies convoluted on the testis, and now takes the name of *epididymis;* it is soon detached from the organ, under the name of *vas deferens;* it ascends towards the inguinal ring, plunges into the pelvis, and very soon arrives at the inferior and anterior part of the bladder; there it communicates both with the vesiculæ seminales and the prostatic portion of the urethra.

The parenchyma of the testicle is enveloped by a fibrous, resisting membrane; it is, besides, covered, 1st, by a serous membrane, called *tunica vaginalis*, which, in the fœtus, made a part of the peritoneum; 2d, by a muscular membrane, which has the power of raising the testicle, and applying it against the inguinal ring; 3d, by the *dartos*, a stratum of very loose cellular tissue, which appears to be contractile; 4th, lastly, by the rugous, tawny skin, which forms the scrotum.

The arterial blood reaches the testicle by a small artery which rises from the aorta as high as the renal arteries. The veins of this organ, before uniting into one trunk, are thick, tortuous, and numerous; they frequently anastomose, and have, collectively, the name of *corpus pampiniforme*. Although the testicles be endowed with great sensibility, it does not appear that any nerve, either of the brain or ganglions, has ever been traced into their substance.

Vesiculæ seminales.

The name of *vesiculæ seminales* is given to two little cellular organs, situated under the lower part of the bladder, and which seem intended to contain the fluid secreted by the testicle. The sides of it are thin, covered internally by a mucous membrane, and externally by a stratum of fibres: it is not known if the intermediate membrane is or is not contractile. The anterior extremity of the vesiculæ communicates with the *vasa deferentia* and the urethra, by a very short, narrow canal, which has been named *ejaculatory*.

Penis.

Lastly, the *penis* belongs to the number of the male genital organs. It is principally formed by the *corpora cavernosa*, the *spongy portion* of the *urethra*, and the *glans*.

Corpora cavernosa.

The *corpora cavernosa* determine, in a great measure, the form and dimensions of the penis; they begin at the internal part of the ramus of the ischium, very soon meet, and form, by their junction, the body of the penis. They are separated from each other by a fibrous partition, pierced with many holes, named *septum perforatum*. They have an exterior membrane, fibrous, hard, dense, and very elastic. In their interior, a great number of filaments and plates cross each other, and by their union form a kind of sponge, into the midst of which the blood is poured. The urethra and the glans, which make also an essential part of the penis, have an analogous parenchyma, but they are not surrounded with a fibrous membrane. Six arterial branches go to the penis. This part receives also several nerves, which arise from the sacral pairs.

The genital organs of man constitute merely an apparatus of glandular secretion, of which the testicle is the gland, the vesiculæ seminales the receptacle, the vas deferens and the urethra, the excretory canal. This secretion is indispensable for generation.

Secretion of semen.

The fluid secreted by the testicles is called *semen*. The small volume of these glands, the number and tenuity of the seminiferous tubes, the small quantity of blood which the spermatic arteries carry to them, the great length and narrowness of the vas deferens, render it probable that its quantity is very inconsiderable, and that it is directed towards the vesiculæ seminales very slowly. It is also probable that the secretion of the semen takes place in a continued manner, but more rapidly by voluptuous excitations, if certain sorts of food have been used, or if the venereal action is often repeated.

It is difficult to conceive how the liquor secreted by the testicle passes through the seminiferous canals, and the epididymis, and how it ascends through the vas deferens. Perhaps there is a capillary effect in this canal, which its narrowness as well as its thickness, and the resistance of its sides render probable. It is a little more easy to comprehend how the semen, having reached the extremity of the vas deferens, can penetrate into the vesiculæ seminales: the ejaculatory canals embraced by the neck of the bladder and by the levatores ani, must resist the approach of the liquid, which thus finds a more free access into the neck of the vesiculæ seminales.

The semen has never been analyzed in the state in which it passes out of the testicle: the fluid which has been studied under this name is formed by the semen, the liquid secreted by the mucous membrane of the vesiculæ seminales, by the prostate gland, and perhaps by Cowper's glands.

Physical and chemical properties of semen.

When this fluid passes out of the urethra it is mixed, and compounded of two substances, the one liquid, slightly opaline, the other thick, almost opaque. Left to themselves, these two matters mix, and the mass liquefies in a few minutes. The odour of semen is strong, and *sui generis;* its taste is salt and somewhat bitter. Professor Vauquelin, who analyzed it, found it composed of

Water - - - - - - -	900.
Animal mucilage - - -	60.
Soda - - - - - - - -	10.
Phosphate of lime - -	30.

Examined by the microscope, a multitude of animalcula are observed in it, which appear to have a round head and a pretty long tail: these animalcula move with considerable rapidity; they seem to fly the light and to seek the shade.

The secretion of the semen begins at the age of puberty; before that time the testicles secrete a viscous transparent fluid, which has never been analyzed, but which, in appearance, differs much from semen.

Influence of its secretion upon the economy.

The modifications of the economy which happen at the same epoch, such as the *moulting* of the voice, the developement of the hair, the increase of the muscles and bones, &c., are connected with the existence of the testicles and the fluid which they secrete. The removal, indeed, of those organs before puberty is opposed to their development. At first eunuchs preserve the forms of infancy; their larynx does not increase, no hair grows on the chin, and their character remains timid; later, their physical and moral qualities approach very nearly those of the female; nevertheless the greater part take pleasure in sexual intercourse, and perform with ardour an act which can never turn to account in the production of the species.

In order that emission of the semen may take place in the healthy state, the spongy tissue of the penis must be distended in all directions, become rigid, warm, in a word, must be in a state of *erection.* In this state every thing announces that the blood arrives in great abundance in the penis, its arteries become larger, pulsate with more force, its veins are swelled, and the temperature is sensibly augmented. These different phenomena are evidently under the influence of the nervous system.

Of erection.

Different explanations of erection have been proposed. It has been referred sometimes to the compression of the pudic veins, or of the *corpora cavernosa* by the muscles of the penis, sometimes to the constriction of the veins by nervous influence, &c.; but can erection, an action purely vital, be explained at all?

Whatever be its nature, it is produced by several very different causes, such as mechanical excitations, venereal desires, fulness of the vesiculæ seminales, the use of certain foods, some medicines, and even certain kinds of poison; it is excited also by several diseases, flagellation, &c.

Of all these causes the imagination is that of which the effect is the most rapid. One of the most remarkable of the phenomena of erection is, doubtless, the quickness of its reproduction, or cessation, in certain cases.

Generally, erection is accompanied by the flow of a certain viscous liquid, which is said to come from the prostate.

Excretion of semen.

The circumstances that bring on the ejection of the semen, as well as the sensation which accompanies it, are known; but the mechanism of its evacuation is much less so. Do the vesiculæ empty themselves in whole or in part in the moment of ejaculation? Is it their middle coat which contracts, or are they compressed by other causes? Do the muscular fasciculi which, from the orifice of the ureters, are directed to the *urethral crest*, concur in it? Is the levator ani relaxed at this instant? Is it the contact of the semen upon the membranous or spongy bodies which excites the sensation that accompanies its expulsion? &c. We know nothing certain respecting these different questions.

Genital Organs of the Female.

Genital organs of the female.

The *ovaria*, the *Fallopian tubes*, the *uterus*, or *matrix*, and the *vagina*, are the essential female organs of generation.

Of the ovaria.

Since the time of Steno, the name of *ovaria* has been given to two little bodies situated in the hollow of the pelvis upon the sides of the uterus. Each ovarium is formed by an exterior fibrous membrane, and interiorly by a peculiar cellular tissue in which are found fifteen or twenty vesicles, some of which are generally more voluminous than the rest, and correspond by one of their sides to the exterior membrane, which is thinner in this place. These vesicles appear to contain the rudiments of the germ, and to be the same in respect of women, that eggs are in respect of birds, reptiles, and fishes. They are formed by two membranous envelopes, and a fluid which coagulates and hardens like albumen. The want of development of the ovaria, which sometimes happens in woman, has an influence upon the whole economy, not similar, but analogous to that of the removal of the testicles. A woman rendered barren from this cause has generally a masculine appearance; her chin and the circumference of her mouth are covered with hair; her taste and character incline to those of man, her voice is grave and sonorous, the clitoris is often considerably enlarged. In this incomplete kind of woman, such as is often called *virago*, an inclination is found that ought to exist only in man, which, though equally a perversion of nature and morality, is not less remarkable under a physiological point of view.

Of the Fallopian tubes.

The Fallopian, or uterine tubes, are two narrow canals which, one on the right, the other on the left, establish a communication between the ovarium and the matrix. They are hollow and fringed in their external extremity; narrow and round in the rest of their extent. Their tissue, especially on the side of the uterus, is analogous to that of the vas deferens.

Of the uterus.

In the hollow of the pelvis, before the rectum, and behind the bladder, is found the uterus, an organ of a pyriform shape, and of small volume in its ordinary state, but destined to undergo a considerable extension during pregnancy. There is distinguished in the uterus, the *body*, which is superior; the *neck*, which is inferior, embraced by the vagina, and a cavity, which has three orifices, two superior, which correspond to the Fallopian tubes, and one inferior, that communicates with the vagina.

Structure of the uterus.

The proper tissue of the uterus is singular of its kind in the animal economy; it has, nevertheless, some analogy with that of the heart: its structure is inextricable in the ordinary state; it is more easily studied in advanced pregnancy: two prolongations of this tissue, under the name of *round ligaments*, go to the inguinal rings, and spread upon the external aspect of the labia; a great part of the external surface of the uterus is covered by the peritoneum, which forms several remarkable folds around this organ. The internal surface is covered by a mucous membrane.—In looking at this surface with a strong lens, a multitude of little openings are perceived in it, some of which, less numerous and wider, belong to the veins of the organ; the others, in much greater number, seem proper to the arterial capillaries.

The arteries of the uterus are tortuous, and very considerable in respect to its volume: the veins are also numerous and large; they form, in the body of its tissue, what anatomists have improperly called *sinus uteri:* the nerves are less numerous, and come from the hypogastric plexus.

Of the vagina.

The cavity of the uterus communicates with the exterior by the *vagina,* a membranous canal placed almost vertically in the pelvis. Its length is from six to seven inches; its width is variable, according as a woman has, or has not, had children. Its internal surface presents, especially on the lower part, a great number of transverse folds, that allow the vagina to become elongated in pregnancy. In the virgin, its inferior extremity is provided with the *hymen*, a thin membrane in form of a crescent, which, in a great measure, shuts up its entrance.

The tissue of the vagina is composed of greyish fibres, crossed in all directions, pretty analogous to those of the uterus. Below it is surrounded by numerous veins, in appearance like the corpus cavernosum, which form the *plexus retiformis*. This part of the vagina is thought susceptible of erection. The whole of the internal surface of this organ is clothed with a membrane that contains many mucous and sebaceous follicles.

External genital parts of woman.

The external parts of the female comprehend the *great* and *small labia*, folds that disappear during child-birth, and the *clitoris*, a kind of small imperforated penis, com posed of two cavernous bodies, and a sort of glans covered by a prepuce. It possesses great sensibility, and an erection like that of the penis.

Of Menstruation.

Menstruation.

In the greater number of women, the aptitude for generation, or impregnation, is marked by a periodical flow of sanguineous matter from the internal surface of the uterus; this is a real sanguineous exhalation; it bears the name of *menses*, *menstruation*, *&c.*, because it returns pretty regularly every month. Some women, however, have their periods every fifteen days, others every two months, others at times indetermined, and, lastly, some never have any menses. Certain particular signs indicate the approach of the menses, such as a feeling of heaviness in the loins, lassitude in the limbs, prickling and pain of the mammæ.—Its appearance is sometimes marked by more serious accidents; at other times it takes place rapidly, without any precursory indication.

Menstruation.

The total duration of the flow, its mode, the quantity of blood exhaled, the colour, the consistence of this blood, are not less variable. In some women, the quantity of menstrual blood is considerable, and amounts to several pounds; the menses last eight or ten days without stopping; the blood has all the qualities of that of the arteries: from others pass scarcely a few drops of blood, at one time watery and deprived of fibrine, and at other times having all the appearance of venous blood; the flow continues scarcely one day, or is repeatedly suspended. Women are subject to great irritability while menstruation continues; the least noise frights them, they are affected by the smallest contradiction, and are very irascible.

The regularity or irregularity of the return of the menses, the nature and quantity of the blood evacuated, the duration of the evacuation, are closely connected with the state of health or sickness of the female, and deserve all the attention of the physician.

It has been ascertained, by opening the bodies of women who died during the period of menstruation, that the blood escapes from the internal surface of the uterus, the vessels of which have been found red, and filled with blood, which, by slight pressure, could easily be made to flow into the cavity of the organ. Although the flow of the menses almost always takes place by the uterus, this organ, however, is not exclusively destined to produce it: women have frequently had their menses from the mucous membrane of the great intestine, from the stomach, the lungs, the eye, &c. Different parts of the skin afford also sometimes an issue to the blood of the menses: thus it has been seen to pass monthly through one or several of the fingers, through the cheek, the skin of the abdomen, &c.

Could it be believed, that authors of note have employed themselves in attempting to discover the immediate cause of the menses, and that they have been attributed to the influence of the moon, the vertical position of woman, to her too abundant nourishment, &c.?

The time of the first menstruation happens, in our climates, about the thirteenth or fourteenth year; it is later in the North, and earlier in warm countries. In the equatorial regions, girls are sometimes marriageable at seven or eight years. About the age of fifty years, later in northern, and sooner in southern countries, the menses cease, and with them the aptitude to generation. This epoch, called *the decline of life, critical period,* &c. is often marked by the development of serious diseases.

What we have just said about menstruation, is subject to numerous exceptions. Young girls have sometimes conceived without having had menses; women, whose menses had ceased at the usual time, have seen them return, at seventy or eighty years, and have become mothers. Lastly, women who have never had any menstruation, have not, on that account, been less fertile.

Coition and Fecundation.

Coition. We have mentioned what instinctive feelings protect our individual existence; a feeling of the same nature, but more strong and imperious, because its end is more important, ensures the preservation of the species, by inclining the sexes to each other, and to perform the act of copulation. The part of the male, in the act of reproduction, is to deposit the semen in the vagina, at a greater or less distance from the orifice of the uterus.

The function which the female discharges is much more obscure; some feel, at this moment, very strong voluptuous sensations; others appear entirely insensible; whilst others, again, experience a sensation which is very painful. Some of them pour out a mucous substance in considerable abundance, at the instant of the most vivid pleasure; whilst, in the greater part, this phenomenon is entirely wanting. In all these respects, there is, perhaps, no exact resemblance between any two females.

These different phenomena are common to the most frequent acts of copulation, that is, to those which do not produce impregnation, as well as those which are effective. What happens additional in these last?

Fecundation. If the most recent works of Physiology are to be credited,* the uterus during impregnation opens a little, draws in the semen by aspiration, and directs it to the ovarium by means of the Fallopian tubes, whose fimbriated extremity closely embraces that organ.

The contact of the semen determines the rupture of one of the vesicles, and the fluid that passes from it, or the vesicle itself, passes into the uterus, where the new individual is to be developed.

However satisfactory this explanation may appear, we must beware of its admission; for it is purely hypothetical, and even contrary to the experiments of the most exact observers.

In the numerous attempts made upon animals by Harvey, de Graaf, Valisneri, &c., the semen has never been

* I pass over the systems of the ancients and the moderns upon generation. Why overload the minds of students with these brilliant reveries, that do more injury than is generally supposed to the progress of science?

perceived in the cavity of the uterus; much less has it been seen in the Fallopian tube at the surface of the ovarium. It is quite the same with the motion which the Fallopian tube is supposed to have in embracing the circumference of the ovarium: it has never been proved by experiment. Even if one should suppose that the semen penetrates into the uterus at the moment of coition, which is not impossible, though it has not been observed, it would still be very difficult to comprehend how the fluid could pass into the Fallopian tubes and arrive at the ovarium. The uterus in the empty state is not contractible, the uterine orifice of the Fallopian tubes is extremely narrow, and these canals have no known sensible motion.

On account of the difficulty of conceiving the passage of the semen to the ovarium, some authors have imagined that this matter is not carried there, but only the vapour which exhales from it, or the *aura seminalis*. Others think that the semen is absorbed in the vagina, passes into the venous system, and arrives at the ovaria by the arteries.* The phenomena which accompany the fecundation of woman are, then, nearly unknown. An equal obscurity rests on the fecundation of other mammiferous females. Nevertheless it would be more easy to conceive a passage of the semen to the ovaria in these, since the uterus and the Fallopian tubes possess a peristaltic motion like that of the intestines. Fecundation, however, taking place by the contact of the semen with the ova, in fishes, reptiles, and birds, it is not very likely that Nature employs any other mode for the *mammifera;* it is necessary, then, to consider it as very probable that, either at the instant of coition, or at a greater or less time afterwards, the semen arrives at the ovarium, where it exerts more especially its action upon the vessels most developed.

But, even should it be out of doubt that the semen arrives at the vesicles of the ovarium, it would still remain to be known how its contact animates the germ contained in it. Now, this phenomenon is one of those on which our senses, and even our mind, have no hold: it is one of those impenetrable mysteries of which we are, and, perhaps, shall ever remain ignorant.

* If this idea had any foundation, a female might be impregnated by injection of the semen into the veins. This experiment would be curious to try.

We have, however, on this subject some very ingenious experiments of Spallanzani, which have removed the difficulty as far as it seems possible.

Experiments upon impregnation.

This philosopher has proved, by a great number of trials, 1st, that three grains of semen, dissolved in two pounds of water, are sufficient to give to it the fecundating virtue; 2d, that the spermatic animalcula are not necessary to fecundation, as Buffon and other authors have thought; 3d, that the *aura seminalis*, or seminal vapour, has no fecundating property; 4th, that a bitch can be impregnated by the mechanical injection of semen into her vagina, &c., &c.

It is thus necessary to consider as conjectural what authors say about the general signs of fecundation. At the instant of conception, the woman feels, it is said, a universal tremor, continued for some time, accompanied by a voluptuous sensation; the features are discomposed, the eyes lose their brilliancy, the pupils are dilated, the visage pale, &c. No doubt, impregnation is sometimes accompanied by these signs; but how many mothers have never felt them, and reach even the third month of their pregnancy without suspecting their situation.

We have more exact notions about the changes that take place in the ovarium after fecundation. All good authors have described a body of a yellowish colour that is developed in the tissue of the ovarium in fecundated females, and which, pretty voluminous at first, become less and less in proportion as pregnancy advances: but these phenomena belong to the history of gestation, upon which we are about to enter.

Pregnancy, or Gestation.

Pregnancy or gestation.

The time which intervenes between the instant of fecundation and child-birth is called *pregnancy* or *gestation*; it is generally nine months, or two hundred and seventy days: all this time is occupied in the development of the organs of the new individual.

In order to have correct notions of pregnancy, it is necessary to study in succession the phenomena that take place in the ovarium after fecundation, those that happen in the Fallopian tube, those that belong to the uterus and its parts, those which are seen in the whole economy, and, lastly, those peculiar to the fœtus.

Notwithstanding the numerous labours of anatomists and physiologists upon the changes that take place in the ovarium after fecundation, we are still far from being sufficiently informed in this respect. The difficulty consists in knowing what is detached from the ovarium to pass into the uterus; some say they have seen a little vesicle detached from the ovarium pass into the Fallopian tube, and others deny even having observed any thing of this kind. I shall explain what I have learned by observation on this point. Action of the ovarium.

Twenty-four or thirty hours after an effective coitus, the vesicles of the ovarium, that were most developed, sensibly augment in volume. The tissue of the ovarium by which they are surrounded becomes more consistent. It changes colour, and becomes of a greyish yellow. Experiments on generation in the ovary.

In this state the tissue of the ovarium over the vesicle takes the name of *corpus luteum*. The vesicle continues to increase the second, third, and fourth day. The *corpus luteum* increases in the same proportion at this epoch: it contains in its areola a liquid, that is white, opaque, and in its appearance analogous to milk.

After this time the vesicle breaks the external tunic of the ovarium, and directs itself to the surface, where it still adheres by one of its sides. In dogs, I have seen vesicles pass out in this manner from the ovarium, that were of the size of an ordinary hazel nut. In this state, they present nothing interiorly that can be considered as a germ; their surface is smooth; the liquid they contain no longer coagulates into a mass, as before impregnation.

After the vesicle has passed out, the *corpus luteum* remains in the ovarium; it presents in its centre a cavity greater in proportion as the time of conception is less distant. This cavity, as well as the *corpus luteum* itself, diminishes as the time increases; but the diminution of the latter is very slow, and the ovary always contains those of preceding impregnations, a circumstance which has often deceived observers. Experiments upon the action of the ovarium.

Thus the first effects of impregnation happen in the ovarium, and consist of the development of one or several vesicles, and of as many *corpora lutea*; sometimes vesicles are found filled with blood; they seem to have been too strongly affected by the semen; it also appears that in certain cases the vesicle of one or more *corpus luteum* breaks before their entire development; for it is not unfrequent to find more *corpora lutea* in the ovarium than vesicles at its surface.

Action of the Fallopian Tube.

Amongst the developed vesicles attached to the surface of the ovarium, there is generally one which adheres to its hollow mucous orifice, the tissue of which is softened, and gorged with blood, and presents an evident peristaltic motion. I have never immediately perceived the vesicle in the Fallopian tube; but I have several times seen a vesicle which had descended as far as the most inferior part of the angle of the uterus, whilst another had already adhered to the extremity of the tube. At this instant the body of the tube was so enlarged as to be near half an inch in diameter: it was therefore of a sufficient size to allow the vesicles to pass.

Action of the uterine tube.

The time at which the vesicles pass through, the tube appears to be variable, according to the kinds of animals. In rabbits it seems to take place from the third to the fourth day; in bitches from the sixth to the eighth. It is probably still later in woman, and perhaps seldom happens before the twelfth. Doctor Maygrier assures me that he has seen the produce of impregnation thrown out by an abortion the twelfth day of pregnancy: it was a little vesicle slightly fleculent at its surface, and full of a transparent liquid. The vascular appendices in which the Fallopian tube terminates in the human species, are probably intended to form adhesions with the vesicle which is detached from the ovarium, and to pour out a fluid on them which may favour their development. After their passage the tube retracts, and resumes its former diameter.

Arrived in the cavity of the uterus, the ovum closely unites with the interior surface of this organ; here it receives the materials necessary for its growth, and acquires a considerable volume. The uterus yields to this augmentation, changes form, position, &c.

Changes of the Uterus in Pregnancy.

Changes of the uterus in pregnancy.

In the three first months of pregnancy the development of the uterus is inconsiderable, and takes place in the hollow of the pelvis; but in the fourth the organ becomes much larger; it can no longer be contained in this cavity;

it rises, and is then lodged in the hypogastrium. The organ continues to increase in all directions during the fifth, sixth, seventh, and eighth months; it occupies a space greater and greater in the abdomen, compresses and displaces the surrounding organs, and crowds the intestines into the lumbar and iliac regions. At the end of the eighth month, it fills nearly alone the hypogastric and umbilical regions; its fundus reaches the epigastric region; after this epoch the fundus sinks towards the umbilicus.

The cervix uteri undergoes little change during the first seven months of gestation, and the organ preserves during this time a conoid figure; but, afterwards, the neck diminishes in length, opens a little, and almost entirely disappears; then the uterus has a perfect ovoid form, and its volume, according to Haller, is nearly twelve times larger than in the empty state.

The uterus cannot possibly change its form, volume, and situation, in this manner, without its relations with the adjoining parts being modified; indeed the peritoneal folds that form the broad ligaments separate, the vagina is increased in length. The ovaria retained by their veins and arteries, cannot rise with the *fundus uteri;* they, as well as the Fallopian tubes, are placed upon its lateral parts. The round ligaments yield to its elevation as far as their length permits; afterwards they present more or less obstacles, and tend to direct the *fundus uteri* forward, which must have an advantageous effect for the abdominal circulation, in lessening the compression of the great vessels. The abdominal parietes suffer a considerable extension; thence the wrinkles that appear on the abdomen of women who have had several children.

Change in the structure of the uterus during pregnancy.

In proportion as the uterus is developed, its tissue loses its consistence; it assumes a pretty deep red colour, and a sponge-like arrangement; its fibrous structure becomes more evident. Longitudinal fibres are seen on the exterior, which run from the *fundus* to the *cervix,* where they are crossed at right angles by circular fibres. (95) Below

(95) Mr. C. Bell, Medico-Chirurgical Transactions, Vol. IV., strongly asserts the muscularity of the uterus, and supports his general arguments by dissection. He has discovered "a muscular layer of fibres which cover the upper segment of the gravid uterus. The fibres arise from the round ligaments, and regularly diverging, spread over the fundus until they unite,

this layer the uterine tissue presents an inextricable interlacement of fibres, where no regular arrangement can be distinguished; in this state the organ seems endowed with a particular contractility, which has in animals the greatest analogy with the peristaltic motion of the intestines; its interior surface presents immediately after impregnation an albuminous layer which strongly adheres to it. This layer increases with the organ in the earlier periods of pregnancy, but in a great measure disappears afterwards. W. Hunter, who first described it with care, called it the *Decidua*. It seems intended to favour the adherence of the ovum to the internal surface of the uterus.*

These changes in the volume and structure of the uterus necessarily produce modifications in its circulation. Indeed, the arteries suffer a very considerable dilatation; the veins also increase much; they form in the parenchyma of the organ what has been improperly called the *sinus uteri:* the lymphatic vessels also become very voluminous. It is evident that the quantity of blood that traverses the uterus in a given time is in relation to the changes it has suffered, and the new functions it is required to fulfil.

General Phenomena of Pregnancy.

Whilst all these phenomena take place in the uterus, important modifications happen in the functions of the mother, and often begin to show themselves immediately after impregnation.

A woman who has conceived has no longer any menstrual discharge; her mammæ swell; if she nurses, her milk becomes serous, and is injurious to the child; her eyelids are swelled and bluish; her visage discoloured; the perspiration takes a peculiar odour; a general paleness prevails, with a disgust for most kinds of food, sometimes accompanied with singular appetites; constant nausea, violent pains of the head are felt, and are followed by

* See his excellent work *de Utero Gravido*, &c.

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and form the outermost stratum of the muscular substance of the uterus." With Haller, he makes the circular fibres most abundant in the vicinity of the fundus, the longitudinal fibres around the cervix. He sees the uterus *contract* distinctly in brutes even when removed from the body; and adds, that the muscular fibres can be distinctly traced on the internal surface of the waters, after brushing off the decidua.

severe vomitings; the abdomen becomes extremely sensible, first flattens to be afterwards inflated; some women lose their sleep, and yet cannot quit their beds without extreme fatigue; on the other hand valetudinary delicate women have their health established: often serious diseases are arrested in their course, and do not recommence until after parturition, &c.

Generally, the faculties of pregnant women are enfeebled, they are affected without reason, the most ordinary events produce in them deep, and almost always gloomy impressions; hence the necessity of those solicitous cares of which a woman becomes the object.

To those different accidents that cannot be explained, are added the phenomena which evidently depend on the increased volume of the uterus: as cramps in the inferior extremities, swelling of the superficial veins of the thighs and legs, a feeling of stiffness, that prickling generally arising from difficulty of circulation. In the latter periods of pregnancy, the bladder and rectum being strongly compressed, frequent inclinations are excited to go to stool, and make urine.

We need not add empty suppositions to these phenomena whose existence is certain; as for example, fractures in pregnant women uniting with more difficulty than those of others: experience proves directly the contrary.

Development of the Ovum in the Uterus.

The ovum, in the first moments of its abode in the uterus, is free and unattached; its volume is nearly that which it had in quitting the ovarium; but, in the course of the second month, its dimensions increase, it becomes covered with filaments of about a line in length, which ramify in the manner of blood vessels, and are implanted into the *decidua*. In the third month they are seen only on one side of the ovum, the others have nearly disappeared; but those which remain have acquired a greater extent, thickness, and consistence, and are more deeply implanted into the deciduous membrane; taken together, they form the *placenta*. The ovum, in the rest of its surface, presents only a soft flocculent layer called *decidua reflexa*. The ovum continues to increase until the end of pregnancy, in which its volume is nearly equal to that of the uterus;

Development of the ovum in the uterus.

but its structure suffers important changes, which we will examine.

At first its two membranes have yielded to its enlargement, whilst becoming thicker or more resisting: the exterior is called *chorion;* the other *amnion.* The liquid contained by the latter augments in proportion to the volume of the ovum. According to Professor Vauquelin, it presents at once acid and alkaline properties. It is formed of water, albumen, soda, muriate of soda, and phosphate of lime: M. Berzelius says he has recognised fluoric acid in it; perhaps it is not identically the same in different periods of gestation. In the second month of pregnancy there exists also a certain quantity of liquid between the chorion and amnion, but it disappears during the third month.

Up to the end of the third week, the ovum presents nothing indicative of the presence of the germ; the contained liquid is transparent, and partly coagulable as before. At this period there is seen on the side where the ovum adheres to the uterus something slightly opaque, gelatinous, all the parts of which appear homogeneous; in a short time, certain points become opaque, two distinct vesicles are formed, nearly equal in volume, and united by a pedicle, one of which adheres to the amnion by a small filament. Almost at the same time a red spot is seen in the midst of this last, from which yellowish filaments are seen to take their rise: this is the heart, and the principal sanguiferous vessels. At the beginning of the second month, the head is very visible, the eyes form two black points, very large in proportion to the volume of the head; small openings indicate the place of the ears and nostrils; the mouth, at first very large, is contracted afterwards by the development of the lips, which happens about the sixtieth day, with that of the ears, nose, extremities, &c.

Of the embryo.

Of the fœtus.

The development of all the principal organs happens successively until about the middle of the fourth month; then the state of the *embryo* ceases, and that of the *fœtus* begins, which is continued till the termination of pregnancy. All the parts increase with more or less rapidity during this time, and draw towards the form which they must present after birth. We have already explained the principal circumstances that regard the relative functions;

a few words remain to be said of nutritive life. Before the sixth month, the lungs are very small, the heart large, but its four cavities are confounded, or at least difficult to distinguish; the liver is large, and occupies a great part of the abdomen; the gall-bladder is not full of bile, but of a colourless fluid not bitter; the small intestine, in its lower part, contains a yellowish matter, in small quantity, called *meconium;* the testicles are placed upon the sides of the superior lumbar vertebræ; the ovaria occupy the same position. At the end of the seventh month, the lungs assume a reddish tint which they had not before; the cavities of the heart become distinct; the liver preserves its large dimensions, but removes a little from the umbilicus; the bile shows itself in the gall-bladder; the meconium is more abundant, and descends lower in the great intestine; the ovaria tend to the pelvis, the testicles are directed to the inguinal rings. At this period the fœtus is capable of life, that is, it could live and breathe if expelled from the uterus. Every thing becomes more perfect in the eighth and ninth months. We cannot here follow the interesting details of this increase of the organs; they belong to anatomy: we shall consider the physiological phenomena that relate to them.

Functions of the Ovum, and of the Fœtus.

Functions of the ovum and the fœtus.

The ovum begins to grow as soon as it arrives in the cavity of the uterus; (96) its surface is covered with asperities that are quickly transformed into sanguiferous vessels: there is then life in the ovum. But we have no idea of this mode of existence; probably the surface of the ovum absorbs the fluids with which it is in contact, and these, after having undergone a particular elaboration by the membranes, are afterwards poured into the cavity of the amnion.

Functions of the germ and of the embryo.

What was the germ before its appearance? Did it exist, or was it formed at that instant? Does the little almost opaque mass that composes it contain the rudiments of all the organs of the fœtus and the adult, or are these created the instant they begin to show themselves? What

(96) For early and thriving birth, see Dr. Rodman's papers in Ed. Med. and Surgical Journal, Vol. XII. p. 251.

can be the nature of a nutrition so complicated, so important, performed without vessels, nerves, or apparent circulation? How does the heart move before the appearance of the nervous system? Whence comes the yellow blood that it contains at first? &c. &c. No reply can be given to any of these questions in the present state of science.

We know very little of what happens in the embryo, whose organs are only yet rudely delineated; nevertheless, there is a kind of circulation recognised. The heart sends blood into the large vessels, and into the rudimentary placenta; probably blood returns to the heart by veins, &c. But when the new being has reached the fœtal state, as most of the organs are very apparent, then it is possible to recognise some of the functions peculiar to that state.

Functions of the fœtus.

The circulation is the best known of the functions of the fœtus; it is more complicated than that of the adult, and is performed in a manner quite different.

In the first place, it cannot be divided into venous and arterial; for the fœtal blood has sensibly every where the same appearance, that is, a brownish red tint: in other respects, it is much the same as the blood of the adult; it coagulates, separates into clot and serum, &c. I do not know why some learned chemists have believed that it does not contain fibrin.

Of the placenta.

The placenta is the most singular and one of the most important organs of the circulation of the fœtus; it succeeds to those filaments which cover the ovum during the first months of pregnancy. Very small at first, it soon acquires a considerable size. It adheres, by its exterior surface, to the uterus, presents irregular furrows, which indicate its division into several lobes or *cotyledons*, the number and form of which are not determined. Its fœtal surface is covered by the chorion and amnion, except at its centre, into which the umbilical cord is inserted. (97) Its parenchyma is formed of sanguiferous vessels, divided and subdivided. They belong to the divisions of the umbilical arteries, and to the radicles of the vein of the same name. The vessels of one lobe do not communicate with

(97) The cord is not implanted exactly in the centre of the placenta, but considerably to one side of it, an expedient by which nature is said much to facilitate the separation of the placenta from the uterus.

those of the adjoining lobes; but those of the same *cotyledon* anastomose frequently, for nothing is more easy than to make injections pass from one to another.

The *umbilical cord* extends from near the centre of the placenta to the umbilicus of the child; its length is often near two feet; it is formed by the two umbilical arteries and the vein, connected by a very close cellular tissue, and it is covered by the two membranes of the ovum. Umbilical cord.

In the first months of pregnancy, a vesicle, which receives small vessels, being a prolongation of the mesenteric artery and the mesenteric vein, is found in the body of the cord, between the chorion and the amnion, near the umbilicus. This vesicle is not analogous to the *allantoïd;* it represents the membranes of the yolk of birds and reptiles, and the umbilical vesicle of the *mammalia.** It contains a yellowish fluid which seems to be absorbed by the veins of its parietes. Umbilical vesicle.

The umbilical vein, arising from the placenta, and then arriving at the umbilicus, enters the abdomen, and reaches the inferior surface of the liver; there it divides into two large branches, one of which is distributed to the liver, along with the *vena porta,* whilst the other soon terminates in the *vena cava* under the name of *ductus venosus.* This vein has two valves, one at the place of its bifurcation, and the other at the junction with the *vena cava.* Umbilical vein. Ductus venosus.

The heart and the large vessels of the fœtus capable of life, are very different from what they become after birth; the valve of the vena cava is large; the partition of the auricles presents a large opening provided with a semilunar valve, called *foramen ovale.* The pulmonary artery, after having sent two small branches to the lungs, terminates almost immediately in the aorta, in the concave aspect of the arch; it is called in this place *ductus arteriosus.* Heart of the fœtus. Foramen ovale. Ductus arteriosus.

The last character proper to the circulating organs of the fœtus, is the existence of the *umbilical arteries,* which arise from the internal iliacs, are directed over the sides of the bladder, attach themselves to the *urachus,*(98) pass Umbilical arteries.

* See the paper of M. Dutrochet, on the *involucra* of the ovum, inserted amongst those of the Medical Society of Emulation, tom. viii., and the beautiful researches of M. Cuvier, on the same subject.—(Annales du Muséum, 1817.)

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(98) The *Urachus* in quadrupeds, is a sac, or canal leading to a sac, called *Allantois,* hanging from their navel, and deriving to it urine from the

out of the abdomen by the umbilicus, and go to the placenta, where they are distributed as has been mentioned above.

Circulation of the fœtus.

According to this disposition of the circulating apparatus of the fœtus, it is evident that the motion of the blood ought to be different in it from that in the adult. If we suppose that the blood sets out from the placenta, it evidently passes through the umbilical vein as far as the liver; there, one part of the blood passes into the liver, and the other into the vena cava; these two directions carry it to the heart by the inferior vena cava; being arrived at this organ, it penetrates into the right auricle, and into the left by the *foramen ovale*, at the instant in which the auricles are dilated. At this instant, the blood of the inferior vena cava is inevitably mixed with that of the superior. How, indeed, could two liquids of the same nature, or nearly so, remain isolated in a cavity in which they arrive at the same time, and which contracts to expel them. I am not ignorant that Sebatier, in his excellent *Treatise on the Circulation of the Fœtus*, has maintained the contrary, but his arguments do not change my opinion in this respect. However it may be, the contraction of the auricles succeeds their dilatation; the blood is thrown into the two ventricles the instant they dilate; these, in their turn, contract, and drive out the blood; the left into the aorta, and the right into the pulmonary artery; but as this artery terminates in the aorta, it is clear that all the blood of the two ventricles passes into the aorta, except a very small portion that goes to the lungs. Under the influence of these two agents of impulsion, the blood is made to flow through all the divisions of the aorta, and returns to the heart by the venæ cavæ. Lastly, it is carried to the placenta by the umbilical arteries, and returns to the fœtus by the vein of the chord.

Use of the foramen ovale.

It is easy to conceive the use of the foramen ovale, and the ductus arteriosus: the left auricle, receiving little or no blood from the lungs, could not furnish any to the left ventricle, if it did not receive it from the opening in the partition of the auricles. On the other hand, the lungs

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bladder. In the human fœtus, which generally secretes no more urine than the absorbents remove, it is, in general, a mere vestige: though now and then monsters are born, in whom its function has been necessary and perfect.

having no functions to fulfil, if all the blood of the pulmonary artery were distributed in them, the impulsive force of the right ventricle would have been vainly consumed; whilst, by means of the ductus arteriosus, the force of both ventricles is employed to move the blood of the aorta; without the joint action of both ventricles, probably the blood could not have reached the placenta, and returned again to the heart.

The motions of the heart are very rapid in the fœtus; they generally exceed 120 in a minute: the circulation possesses necessarily a proportionate rapidity.

A delicate question now presents itself for examination. What are the relations of the circulation of the mother with that of the fœtus? In order to arrive at some precise notion on this point, the mode of junction of the uterus and placenta must first be examined.

Relations of the circulation of the mother with that of the fœtus.

Anatomists differ in this respect. It was long believed that the uterine arteries anastomosed directly with the radicles of the umbilical vein, and that the last divisions of the arteries of the placenta opened into the veins of the uterus; but the acknowledged impossibility of making matters injected into the uterine veins pass into the umbilical veins, and reciprocally to cause liquid matters injected into the umbilical arteries to reach the veins of the uterus, caused this idea to be renounced (99). It is at present generally admitted, that the vessels of the placenta and those of the uterus do not anastomose. I have made some researches on this subject, of which I here present the principal results.

Experiments on the circulation of the fœtus.

I first attempted injections of the placenta by the vessels of the uterus, but without any success; I even tried it on living animals, without succeeding better; I employed poisonous matters, of which I knew the effects, and also odoriferous substances, but I could not suspect any direct communication.

In bitches, about the midde of their gestation, there are seen a great number of little arteries, which, issuing from

(99) Formerly (1788) Dr. Handy succeeded in passing injections from the maternal vessels into the cord: and more lately Professor Tiedeman has been equally successful with the prussiate of potass. Should positive or negative experiments have most weight here? perhaps the former, though the many sources of error, at least in Dr. Handy's experiments, render the logical rule of *unam affirmationem centum negationes valere*, somewhat doubtful here.

the tissue of the uterus, pass into the placenta, where they are divided into several ramifications. At this period, it is impossible to separate these two organs, without tearing these arteries, and producing a considerable hæmorrhage; but, at the end of gestation, by drawing the uterus, however slightly, these small vessels, with their divisions, separate from the placenta, and no bleeding happens.

When a quantity of camphor is injected into the veins of a dog, the blood soon takes a strong odour of camphor. After having made this injection in a bitch with pups, I extracted a fœtus from the uterus: at the end of three or four minutes, its blood had no odour of camphor; only a second fœtus, extracted after a quarter of an hour, had a strong odour of camphor. It was the same with the other fœtuses.

Thus, notwithstanding the want of direct anastomosis between the vessels of the uterus and those of the placenta, it cannot be doubted that the blood of the mother, or some of its aliments, passes promptly into the fœtus; it is probably deposited by the uterine vessels at the surface, or in the tissue of the placenta, and absorbed by the radicles of the umbilical vein.

It is much more difficult to know if the blood of the fœtus returns to the mother.

In animals, amongst the small vessels which go from the uterus to the placenta, there is not one which has the appearance of a vein. In woman, large openings, that communicate with the uterine veins, are seen in the part of the uterus to which the placenta adheres; but it is not known whether these venous orifices are intended to absorb the blood of the fœtus, or to allow that of the mother to escape at the surface of the placenta: I would more willingly admit the latter idea, but no proof exists.

I have often injected very active poisons into the vessels of the chord, directing them towards the placenta, but I have never seen the mother suffer from the effects of them, and if she dies of hæmorrhage, the vessels of the fœtus remain full of blood.

Since the anastomosis of the vessels of the uterus does not exist, it is not very likely that the circulation of the mother has any other influence on that of the fœtus, except in pouring blood into the areolæ of the placenta: the heart of the fœtus will, then, be the *primum mobile* of its blood.

Fœtuses have been noticed, however, well formed, that were born without a heart. But are these observations very correct? There are well proved cases of placentas entirely separated from the fœtuses, which were dead, and which still continued to grow. M. Ribes recently observed a case in which the umbilical cord was broken, and perfectly cicatrized. How, then, had the circulation taken place in this organ?

Let us conclude that the relations of the circulation of the mother with that of the fœtus, require new experiments.

Some authors have advanced, that the placenta is to the fœtus what the lungs is to the child that breathes; others have endeavoured to explain the large volume of the liver, in attributing the same use to it. These assertions are unfounded. A dark obscurity surrounds what regards the functions of the supra-renal capsules, the thymus, and thyroid gland, whose dimensions are considerable in the fœtus; this subject has often occupied the imagination of Physiologists, without any real advantage to science.

Digestion of the fœtus.

Notwithstanding the high authority of Boerhaave, it cannot be admitted that the fœtus continually swallows the water of the amnion, and digests it for its nourishment. Its stomach, indeed, contains a viscid matter in considerable quantity; but it has no resemblance to the *liquor amnii*, it is very acid, and gelatinous; towards the pylorus, it is somewhat grey, and opaque; it appears to be converted into chyme in the stomach, in order to pass into the small intestine, where, after having been acted upon by the bile, and perhaps by the pancreatic juice, it furnishes a peculiar chyle. The remainder descends afterwards into the large intestine, where it forms the meconium, which is evidently the result of digestion during gestation. Whence does the digested matter come? It is probably secreted by the stomach itself, or descends from the œsophagus; there is nothing, however, to prevent the fœtus from swallowing, in certain cases, a few mouthfuls of the liquor amnii; and this seems to be proved by certain hairs, like those of the skin, being found in the meconium. It is important to remark, that the meconium is a substance containing very little azote. Nothing is yet known regarding the use of this digestion of the fœtus; it is probably not essential to its growth, since infants have been born without a stomach, or any thing similar.

Some persons say they have seen chyle in the thoracic duct of the fœtus; I have never seen any thing of this kind: In living animals, this canal and the lymphatics contain a fluid analogous to lymph, and which, like it, coagulates spontaneously.

Venous absorption of the fœtus. I once attempted to ascertain, in a direct manner, if venous absorption exists in the fœtus still *in utero*. I injected very active poisonous substances into the pleura, the peritoneum, and the cellular tissue, but I obtained no satisfactory result; for the nervous system of fœtuses that have not yet breathed, does not seem sensible to the action of poisons.

Exhalations of the fœtus. Exhalations seem to take place in the fœtus; for all its surfaces are lubricated nearly in the same manner as afterwards; fat is in abundance; the humours of the eye exist; cutaneous transpiration very probably takes place also, and mixes continually with the liquor amnii. With regard to this last liquor, it is difficult to say whence it derives its origin; no sanguiferous vessels appear to be directed to the amnion, and it is nevertheless probable that this membrane is its secreting organ.

Follicular secretions of the fœtus. The cutaneous and mucous follicles are developed, and seem to possess an energetic action, especially from the seventh month; the skin is then covered by a pretty thick layer of fatty matter, secreted by the follicles: Several authors have improperly considered it as a deposit of the liquor amnii. The mucus is also abundant in the two last months of gestation.

Glandular secretions of the fœtus. All the glands employed in digestion have a considerable volume, and seem to possess some activity; the action of the others is little known. It is not known, for example, whether the kidneys form urine, or whether this fluid is injected by the urethra into the cavity of the amnion. The testicles and mammæ seem to form a fluid that resembles neither milk nor semen, and which is found in the *vesiculæ seminales* and lactiferous canals.

What can be said about the nutrition of the fœtus? Physiological works contain only vague conjectures on this point; it appears certain that the placenta draws from the mother the materials necessary for the development of the organs, but what these materials are, or how they are directed, we do not know.

Animal heat in the fœtus. There being no respiration before birth, the animal heat of the fœtus cannot depend on it. It has been shown by experiment, that it does not rise above 92.75° F., or 95° F.; it is said to be more elevated when the fœtus lies dead in the uterus. If this fact is correct, the fœtus must possess a means of lessening the temperature that does not exist after birth.

This is the little that is known regarding the nutritive functions of the fœtus; what relates to the relative functions has been already explained.

Relation of the functions of the mother with those of the fœtus.

Since the mother transmits to the fœtus the materials necessary for its nutrition, it is necessarily connected with the nature and quantity of materials transmitted: if they are of a good kind, and if the quantity is sufficient, the growth will take place in a proper manner; but if the proportion is too small, or the quantity of them unsuitable, the fœtus will be ill fed, will cease to grow, or will perish. (100) Now, the situation of the mother being able to modify the proportion and the nature of the elements that pass to the placenta, it is just to say that her imagination must have an influence on the fœtus. It is thus that sudden terror, violent anger, immoderate joy, may cause the death of the fœtus, or retard its growth. Physical causes, as blows, falls, the action of certain medicines, the bad quality of food, may have the same result, because, in the same manner, they injure the transmission of the nutritive materials of the fœtus. If the mother is affected with a contagious disease, the fœtus presents the symptoms of it very soon. Thus the life of the fœtus evidently depends on that of the mother.

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(100) Dr. Jeffery, the present learned Professor of Anatomy in the university of Glasgow, relates in his Inaugural Essay *De Placenta*, P. 41., an experiment which seems to prove that the blood returned from the placenta is *arterial*, whilst that sent along the cords to it by the arteries, is *venous*. He secured the umbilical cord of a newly born infant, whilst it lay in the midwife's lap, by three ligatures; and then separated it from the Umbilicus by incision. On puncturing respectively the vein and arteries which compose it, he found that the blood of the vein was *scarlet*, that of the arteries of a *modena* colour: "*Hic, sanguinis in adulti arteriis more, vivide florebat: Ille, venosi sanguinis instar, nigricabat.*" As, however, many learned and dexterous operators have totally failed in this experiment, and as Dr. Jeffery took time to dissect away the gelatinous matter of the cord, though it is well known that a ligature for a single half-hour over a vein renders its blood arterial; certainly it would be very interesting to have it repeated. Some of the teachers of midwifery must frequently see favourable opportunities for the attempt: and by a few hours' labour at most, they might set to rest an important, and highly curious physiological question.

Diseases of the fœtus.

Besides injuries which happen to it from this source, the fœtus is frequently attacked with spontaneous diseases, as dropsies, fractures, ulcers, gangrene, cutaneous eruptions, the separation of some of the extremities, and many other local, general, or interior injuries. These diseases often produce its death before birth, or if it reach that period, they prevent its living beyond it. The membranes of the ovum, the placenta, the liquor amnii, are not always foreign to these disorders.

Vicious conformations.

By the effect of unknown causes, the different parts of the fœtus are sometimes developed in a vicious manner; one, or several of the natural openings of its body, may not exist, or be closed by membranes; the lungs, stomach, bladder, kidneys, liver, and brain, are sometimes wanting entirely, or present unusual appearances; generally, according to the remark of M. Beclard, when a nerve is wanting, the part to which it is principally distributed does not exist.

Monstrosities.

Other *malformations*, or *monstrosities*, which happen also from unknown causes, seem to depend on the confusion of two germs, or embryos: whence result children with two heads and one body, or with two trunks and only one head; some have four arms and four legs, well or ill formed. Fœtuses not developed have been found several times in the abdomen of individuals advanced in age, &c. There is no reason to believe that the imagination of the mother can have any effect on the formation of these monsters; productions of this kind, indeed, are daily observed among animals and plants.

Multiple pregnancies.

Instead of one fœtus, it is not singular for the uterus to contain two. This case happens in France once in eighty; it seems to be still more frequent in England. The gestation of three fœtuses is much more rare: in 36,000 births, which have happened at the *Hospice de la Maternité*, at Paris, it has been only four times observed. We have some authentic examples of women who have had four, and even five fœtuses at a time; but beyond this number the relations of authors seem entirely fabulous. In these multiple pregnancies, the volume and weight of the fœtuses are in relation to their number; twins are smaller than ordinary fœtuses; triple and quadruple births are much more so; but, whatever is their dimension, they are each surrounded by their own amnion and chorion, and have each a distinct placenta. Thus, they possess a distinct, independent existence, so that one may die at a very early period of pregnancy, whilst the others continue.

Nothing inclines us to believe that, in multiple pregnancies, fecundation takes place at two or three different times, and that *superfetation* really exists. (101) Histories that are related in this respect are far from presenting the degree of certainty necessary in a science of facts.

Of Childbirth.

After seven months of pregnancy, the fœtus has all the conditions for breathing, and exercising its digestion; it may then be separated from its mother and change its mode of existence; childbirth rarely, however, happens at this period: most frequently the fœtus remains two months longer in the uterus, and it does not pass out of this organ till after the revolution of nine months. Childbirth.

Examples are related of children being born after ten full months of gestation, but these cases are very doubtful, for it is very difficult to know exactly the period of conception. Our present legislature, however, has fixed the principle, that childbirth may take place the 299th day of pregnancy.

Nothing is more curious than the mechanism by which the fœtus is expelled; every thing happens with wonderful precision; all seems to have been foreseen, and calculated to favour its passage through the pelvis, and the genital parts.

The physical causes that determine the exit of the fœtus are the contraction of the uterus and that of the abdominal muscles; by their force the liquor amnii flows out, the head of the fœtus is engaged in the pelvis, it goes through it, and soon passes out by the valve, the folds of which disappear; these different phenomena take place in succession, and continue a certain time: they are accompanied with pains more or less severe, with swelling and softening of the soft parts of the pelvis, and external genital parts, and with an abundant mucous secretion in the cavity of the vagina. All these circumstances, each in its own way, favour the passage of the fœtus.

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(101) See an indubitable case of Superfœtation in Dr. Elliotson's excellent translation of Blumenbach, p. 371.

To facilitate the study of this complicated action, it must be divided into several periods.

First period of childbirth.

The first period of Childbirth.—It is constituted by the precursory signs. Two or three days before childbirth, a flow of mucus takes place from the vagina, the external genital parts swell, and become softer, it is the same with the ligaments that unite the bones of the pelvis; the *cervix uteri* flattens, its opening is enlarged, its edges become thinner; slight pains, known under the name of *flying pains*, are felt in the loins and abdomen.

Second period of childbirth.

Second period.— Pains of a peculiar kind come on: they begin in the lumbar region, and seem to be propagated towards the *cervix uteri*, or the *rectum;* they are renewed only after considerable intervals, as a quarter, or half an hour. Each of them is accompanied with an evident contraction of the body of the uterus, with tension of its neck, and dilatation of the opening; the finger directed into the vagina discovers that the envelopes of the fœtus are pushed outward, and that there is a considerable tumour which is called *the waters:* the pains very soon become stronger, and the contractions of the uterus more powerful; the membranes break, and a part of the liquid escapes; the uterus contracts on itself, and is applied to the surface of the fœtus.

Third period of childbirth.

Third period.—The pains and contractions of the uterus increase considerably; they are instinctively accompanied by the contraction of the abdominal muscles. The woman who is aware of their effect is inclined to favour them, in making all the muscular efforts of which she is capable: her pulse then becomes stronger and more frequent; her face is animated, her eyes shine, her whole body is in extreme agitation, perspiration flows in abundance. The head is then engaged in the pelvis; the occiput, placed at first above the left acetabulum, is directed inward and downward, and comes below and behind the arch of the pubis.

Fourth period of childbirth.

Fourth period.—After some instants of repose the pains and expulsive contractions resume all their activity; the head presents itself at the vulva, makes an effort to pass, and succeeds when there happens to be a contraction sufficiently strong to produce this effect. The head being once disengaged, the remaining parts of the body easily follow on account of their smaller volume. The section of the umbilical cord is then made, and a ligature is put round it at a short distance from the umbilicus.

Fifth period of childbirth.

Fifth period.—If the accoucheur has not proceeded immediately to the extraction of the placenta after the birth of the child, slight pains are felt in a short time, the uterus contracts feebly, but with force enough to throw off the placenta, and the membranes of the ovum: this expulsion bears (in France) the name of *delivery*. During the twelve or fifteen days that follow childbirth, the uterus contracts by degrees upon itself, the woman suffers abundant perspirations, her mammæ are extended by the milk that they secrete; a flow of matter, which takes place from the vagina, called *lochia*, first sanguiferous, then whitish, indicates that the organs of the woman resume, by degrees, the disposition that they had before conception.

As soon as the child is separated from the mother, and sometimes before, it dilates its thorax, and draws the air into the lungs, which permit themselves gradually to be distended in proportion as the motions of inspiration are repeated: from this instant respiration is established, and will remain till the end of life. The distension of the lungs by the air permits the blood of the pulmonary artery to pass into them, and so much less of it passes through the ductus arteriosus, which contracts by degrees, as well as the foramen ovale, and is obliterated altogether. The same phenomenon takes place in the abdomen, with regard to the umbilical vein and arteries, which are transformed into a kind of fibrous ligament.

The new-born infant is from eighteen to twenty inches in length, and in weight from five to six pounds. Generally, the number of births of boys is greater than that of girls. The number of children that can be born of the same mother do not exceed the number of vesicles in the ovarium, that is about forty.

Of Nursing.

The painful action that we have just been studying does not finish the part that nature has assigned to the female in generation; she owes other cares to the new-born infant: she must protect it against the intemperance of the air, and the seasons; she must watch over its preservation, and its physical and moral education; finally, she must provide its first food, that which is alone suitable for the delicacy of its organs.

Of the mammæ.

This food is the milk; it is secreted by the mammæ, the number, form, and situation of which are distinctive characters of the human species. Their parenchyma is quite distinct from that of the other secreting organs.—Each mamma has twelve or fifteen excretory canals, which open on the top, or upon the sides of the *nipple*. The arteries that go to the mammæ are small but very numerous; they have abundance of lymphatic vessels, as well as nerves: thus, they possess a strong sensibility.—The nipple, particularly, is very sensible, and susceptible of a state analogous to erection.

Up to the period of fecundation the mammæ are inactive, or at least have no apparent secretion; but from the first periods of pregnancy, particular pricklings and shootings are felt in them, and they increase in size. After a certain time, especially about the end of gestation, a serous fluid flows from the nipple, which is sometimes in considerable abundance, and is called *colostrum*. The secretion has often the same characters for two or three days after parturition; but the milk, properly so called, soon appears, and it is this liquid which the mammæ furnish until the termination of nursing.

The milk is one of the most azotised glandular liquids; its colour, odour, and savour, are known to every body: according to M. Berzelius, it is composed of milk, properly so called, and of cream.

The milk contains:

Water	928.75
Cheese, with a trace of sugar	28.00
Sugar of milk	35.00
Muriate of potass	1.70
Phosphate	0.25
Lactic acid, acetate of potass, and lactate of iron	6.00
Phosphate of lime	0.30

Cream contains:

Butter	4.5
Cheese	3.5
Whey	92.0

In this last, 4.4 of sugar of milk, and salt, is found.

It has been long since observed, that the quantity and the nature of milk changes with those of the aliments, and this fact gave rise to the singular opinion, that the lymphatics were the vessels intended to carry to the mammæ the materials of their secretion; but the milk, like the urine, varies in its properties according to the solid or liquid substances introduced into the stomach. For example, the milk is in greater abundance, thicker, less acid, if the woman is fed with animal matters; it is less abundant, less thick, and more acid, if she has made use of vegetables. Milk assumes peculiar qualities if the woman has taken medicinal substances; for example, it becomes purgative if she has used rhubarb, or jalap, &c.

The secretion of milk is prolonged until the period in which the organs of mastication have acquired the development necessary to the digestion of ordinary aliments; it ceases only in the second year. Secretions of milk.

Though the secretion of milk seems proper to woman after parturition, it has been seen sometimes in virgins, and even in man*.

OF SLEEP.

In terminating the history of the relative functions, we have said that these functions were periodically suspended; we added that, during this suspension, the nutritive and generative functions were modified: the period is now arrived for the examination of these phenomena. Of sleep.

When the time of being awake has continued for sixteen or eighteen hours, we have a general feeling of fatigue and weakness; our motions become more difficult, our senses lose their activity, the mind becomes confused, receives sensations indistinctly, and governs muscular contraction with difficulty. We recognise, by these signs, the necessity of *sleep;* we choose such a position as can be preserved with little effort; we seek obscurity and silence, and sink into the arms of oblivion.

The man who slumbers, loses successively the use of his senses; the sight first ceases to act by the closing of

* I have not thought it proper to introduce into this work, which is merely an elementary summary, more particular descriptions of the ages, sexes, temperaments, zoological characters of men, the varieties of the human species, &c.; these considerations belong to natural history and hygiène. See the articles *hygiène* of the *Encyclopédie Methodique*, and the new work of M. Cuvier on the *Règne Animal.*

the eyelids, the smell becomes dormant only after the taste, the hearing after the smell, and the touch after the hearing: the muscles of the limbs, being relaxed, cease to act before those that support the head, and these before those of the spine. In proportion as these phenomena proceed, the respiration becomes slower and more deep; the circulation diminishes; the blood proceeds in greater quantity to the head: animal heat sinks; (102) the different secretions become less abundant. Man, although plunged in this sopor, has not, however, lost the feeling of his existence; he is conscious of most of the changes that happen in him, and which are not without their charms; ideas more or less incoherent, succeed each other in his mind; he ceases, finally, to be sensible of existence: he is *asleep.*

During sleep, the circulation and respiration are retarded, as well as the different secretions, and, in consequence, digestion becomes less rapid.

I know not on what foundation the most part of authors say that absorption alone acquires more energy. Since the nutritive functions continue in sleep, it is evident that the brain has ceased to act, only with regard to muscular contraction, and as an organ of intelligence, and that it continues to influence the muscles of respiration, the heart, the arteries, the secretions, and nutrition.

Sleep is *profound* when strong excitants are necessary to arrest it; it is *light* when it ceases easily.

Sleep, such as it has been described, is perfect, that is, it results from the suspension of the action of the relative organs of life, and from the diminution of the action of the nutritive functions; but it is not extraordinary for some of the relative organs of life to preserve their activity during sleep, as it happens when one sleeps stand-

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(102) In Dr. Corden Thomson's experiments upon human heat, it was found, that there is no difference whatever between the heat of a waking and a sleeping man; (P. ult.) but that, *in those hours wherein sleep usually takes place;* namely, from 12 P. M. till morning, particularly in *summer*, (for in winter it is little changed) the heat falls about 1 degree; and this the Doctor thinks may account for the mistake of J. Hunter, who says, (An. Econ. 101.) "when a man is asleep he is colder than when awake,—the difference in general I find is 1½ degrees, more or less." It must be confessed, however, that in sleep the power of *resisting* cold is less, and therefore a sensation of cold usually perceived when awaking from sleep, may easily have given rise to the notion of our *absolute* cold also being increased, *i. e.* of our heat being diminished.

ing; it is also frequent for one or more of the senses to remain awake, and transmit the impressions which it perceives to the brain; it is still more common for the brain to take cognisance of different internal sensations that are developed during sleep, as wants, desires, pain, &c. The understanding itself may be in exercise in man during sleep, either in an irregular and incoherent manner, as in most dreams, or in a consequent and regular manner, as it happens in some persons happily organized.

The turn which the ideas assume during sleep, or the nature of dreams, depends much on the state of the organs; if the stomach is overcharged with indigested food, the respiration difficult on account of position, or other causes, dreams are painful, fatiguing; if hunger is felt, the person dreams of eating agreeable food; if it is the venereal appetite, the dreams are erotic, &c. The character of dreams is no less influenced by habitual occupations of the mind; the ambitious dreams of success or disappointments, the poet makes verses, the lover sees his mistress, &c. It is because the judgment is sometimes correctly exercised in dreams, with regard to future events, that in times of ignorance the gift of divination was attributed to them.

Nothing is more curious in the study of sleep than the history of *sleep-walkers*. (103)

Those individuals being first profoundly asleep, rise all at once, dress themselves, see, hear, speak, employ their hands with ease, perform certain exercises, write, compose, then go to bed, and preserve, when they awake, no recollection of what happened to them. What difference is there, then, between a sleep-walker of this kind and a man awake? A very evident difference,—the one is conscious of his existence, and the other is not.

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(103) *Sleep-walkers* afford a most perplexing object of study. Their state seems to be a compound of temporary mania, reverie, and actual sleep, but as we have never been able to ascertain the exact state of the mind in any one of these conditions, it can hardly be expected that we should be able to explain that which is compounded of them all. There is no one of the five external senses, which they have not been observed to enjoy, or to want, during the paroxysm: of the internal senses, the imagination seems the most vivid, the judgment the weakest. Dr. Hibbert (Theory of Apparitions) beautifully explains the laws of sleep, in all its modes, by the variations in the relative intensity of sensations and ideas, producing different degrees of consciousness to external objects.

We will not, like certain authors, seek the proximate cause of sleep, and find it in the depression of the laminæ of the cerebrum, the afflux of blood to the brain, &c. (104) Sleep, which is the immediate effect of the laws organiza-

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(104) An ingenious Theory of Sleep, founded on chemical principles, has lately been promulgated. In sleep, it is said, the breathing becomes slower, less carbon is given out, and consequently, some of its compounds, *carburetted hydrogen*, or *carbonic oxid*, or *carbonic acid*, accumulates in the vascular system, and in the course of circulation, is applied to the brain. But all these gases are notoriously soporific, and will avail to keep the person asleep. But how is he first put asleep, or even rendered sleepy? Nothing is plainer, replies our theorist. The exhaustion of the diurnal stimulation and exercise reduce the irritability to that point, where the stimulus imparted by external objects, is just sufficient to keep him awake. Then the man is said to be sleepy; and it is all one whether we add a little to the exhaustion by a sedative, or substract a little from the stimulus;—in either case the equilibrium is overset, the excitement of the external world no longer balances the excitability, and of course, is not felt: in other words the man is said to be asleep. Now, before actual sleep, both pulse and breathing are slower, from the previous exhaustion; therefore carbon is accumulated in one or other of its soporific combinations; but the sedative effect of this, added to the previous exhaustion, easily depresses the excitability below that point where mundane irritants can affect the body. It lulls him to sleep. As to the *phenomena* of sleep, we no more ought to expect to be able to explain them, than any of the effects of any other sedative upon the brain. They are all the result of the peculiar sensibilities of that organ, which are still but vaguely understood. Again, it may be asked, how, since this carbonic sedative goes on increasing, does the sleeper, after a certain period awake? ought not his sleep to grow deeper and deeper? Quite otherwise, our theorist again replies. During sleep, the nutritive process is busily at work to repair the irritability lost through the day; and being now undisturbed by the external world, soon accomplishes its task; but in such a manner that the *sum* of the excitability, old and new, is made more than necessary to counterbalance the sedative influence of the gas, becomes therefore again available to the external world, which STIMULATES it, and is PERCEIVED.

Mr. W. Brande has lately demonstrated that every ounce of the blood contains at least two cubic inches of carbonic acid gas, and Doctors Prout and Fyfe, that the quantity exhaled from the lungs varies according to the food and drink, and the times of the day. But as both the carbon passed off by the lungs, and the carbonic acid circulating in the blood, must be furnished by the same chyle, it is probable, that when the pulmonary carbon is diminished, the sanguineous carbon, or combination of carbon, is proportionally increased. Now the twelve hours of the day in which the carbonous *excretion* is least, fall between nine at night and nine of the morning, the most natural season of rest, and it seems quite obvious to conclude, that it becomes so, merely on account of the increased quantity of carbonic acid retained in the system. Infants and Hybernating animals confirm the same view; since the former possess only carbonated blood, the latter have a slower respiration, incapable of giving out the necessary quantity of carbon. Hence both sleep soundly,—since there occur no changes in the irritability or nutrition, rude enough to awaken them.

tion, cannot depend on any physical cause of this kind. Its regular return is one of the circumstances that contributes the most to the preservation of health; its suppression, even for a short time, is often attended with serious inconvenience, and in no case can it be carried beyond certain limits.

The ordinary duration of sleep is variable; generally, it is from six to eight hours: fatigue of the muscular system, strong exertions of the mind, lively and multiplied sensations, prolong it, as well as habits of idleness, the immoderate use of wine, and of too strong aliments. Infancy, and youth, whose life of relation is very active, have need of longer repose; riper age, more frugal of time, and tortured with cares, devotes to it but a small portion. Very old people present two opposite modifications, either they are almost always slumbering, or their sleep is very light; but the reason of this latter is not to be found in the foresight they have of their approaching end.

By uninterrupted peaceable sleep, restrained within proper limits, the powers are restored, and the organs recover the facility of action; but if sleep is troubled by disagreeable dreams, and painful impressions, or even prolonged beyond measure, very far from repairing, it exhausts the strength, fatigues the organs, and sometimes becomes the occasion of serious diseases, as idiotism, and madness. (105)

OF DEATH.

The individual existence of all organized bodies is temporary; none escapes the hard necessity of ceasing to be, or of dying; man suffers the same fate. Of death.

The history of the individual functions has shown us that from the first periods of old age, and sometimes

(105) Sir Harry Halford, in the Medical Communications, has an account of a singular affection which he denominates the *disease* of old age, consisting of an universal languor and inertness of the functions, without any manifest cause, and from which they sometimes recover not less unaccountably. But what is most wonderful, is the entire immunity of the female sex from this malady. The adage, *vetula corvo annosior* is familiar; but it was hardly to be expected that she would escape a disease arising from old age, a state which never fails to come, at last, to all.—*Med. Trans.* IV. 314.

sooner, the organs become deteriorated; that many of them entirely lose their action; others are absorbed and disappear; that, finally, at the age of decrepitude, life is reduced to some remains of the three vital functions, and to a few deteriorated nutritive functions. In this state, the least external cause, the smallest blow, the slightest fall, is sufficient to arrest one of the three functions indispensable to life, and death immediately arrives as the last term of destruction of the functions and organs.

But few men arrive at this end brought on by the progress of age alone. Of a million of individuals, but a very few attain to it: the others die at all periods of life, by accidents, or diseases, and this great destruction of individuals by causes apparently accidental, seems to enter into the views of nature as well as the precautions she has taken to ensure the reproduction of the species.

TABLE OF THE TISSUES OF THE HUMAN BODY.

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. Animal.		Saline.	
I. CELLULAR. Serous - - - - - - - - Adipose - - - - - - - Situation. SEROUS every where except brain: ADIPOSE every where except viscera, eyelids, nose, penis, scrotum.	Whitish semi-pellucid filaments, variously interwoven, with interstices, communicating in SEROUS, not in ADIPOSE; soft, extensible, contractile; insensible, rapidly inflaming; pours out serum, coagulable lymph, or suppurates.	Gelatine - - -	100	Common salts - Water - - - - -	0.08 ?
II. NERVOUS, of animal life. S. Brain, spinal marrow, their nerves.	Composed of white, slender, parallel filaments, united into bundles of a large size, arising in pairs from the brain and spinal chord; pain terribly when irritated.	Albumen - - - White fat - - - Red fat - - - - Osmazome - - Phosphorus - -	7.0 4.5 0.7 1.1 1.5 ——— 14.8	Water - - - - Phosphate lime Phosph. soda - - Sulphur - - - - - Ph. Ammonia - V.	80.0 } 5.2 ——— 85.2
III. NERVOUS, of organic life. S. Sympathetic nerve, its ganglions.	System of nerves and ganglions, not connected with the cerebral mass, nor symmetrical; not connected with the brain; scarcely give pain on being irritated; scarcely influence their muscles.	*Same* as II.			
IV. ARTERIAL. S. Every where, except epidermis, &c.?	Coats stronger, whiter—section patent; fibres of middle coat transverse; internal without valves, readily ruptured, or ossified; not readily inflamed.	No fibrin? Berzelius. Fibrin? Magendie, p. 307.			

TABLE OF THE TISSUES OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
V. VENOUS. S. Every where. Except epidermis, &c.?	Coats thin, flesh coloured; collapsing when cut; fibres of the middle coat longitudinal; cellular, dense, unalterable; internal tearing across—frequent valves—not readily inflamed—not readily ossified.	——	——
VI. EXHALANTS. S. Every where, on surfaces.	Arise from arteries; carry no red blood; open on surfaces; exhale different fluids from different surfaces.	——	——
VII. ABSORBENTS AND THEIR GLANDS. S. Every where; except the brain, eye, cartilages, serous membranes, placenta, bone, &c.?	Transparent, valvular, contractile; ramify and pass through glands: continue to act after death; easily inflamed; glands obovate, soft.	——	——
VIII. OSSEOUS. S. Centre of limbs; walls of cavities: cavities.	White, partly soluble in acids, inflexible; hollow, insensible; pouring out callus when broken; fibrous; resists putrefaction.	Cartilage - - 33.0 Oil? - - - - Gelatine? - - —— 33.0	Water - - - - - ? Phosph. lime - - 54.0 Carb. lime? - - 10.0 Phosph. magn. - 1.0 Fluate lime - - 2.0 Soda - - - - - 2.0 *Sulph. lime?* - - 1.0 —— 70.0

TABLE OF THE TISSUES OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
IX. MEDULLARY. Of spongy bones - - - Of long bones - - - -	In spongy bones, a vascular network, or *reticulum*, containing a peculiar oil; cells communicate; very subject to inflammation.	Pure medul. oil - 96.0 Albumen - - - Gelatine - - - - Extractive - - - Peculiar matter } 3.0 99.0	Phosph. lime - - ? Carb. lime - - - ? Soda - - - - - ? Water - - - - 1.0 1.0
S. Internal cavities of bones.	In long bones, a membrane, contractile, sensible; rapidly suppurates, and destroys the bone.		
X. CARTILAGINOUS.	Broader than thick, hard, elastic, whitish; apparently inorganic, but really constituted of fibres, which break when strongly bent. Cellular membrane and colourless vessels interposed. Insensible, almost imputrescible; no sympathies; tinges readily in jaundice; desquamates readily from inflammation. Ossifies in old age.	Coagulated albumen, 98	Common salts - - 2.0 Water - - - - ?
S. Ends of bones; synchondroses, walls of cavities.			
XI. FIBROUS. Membranous - - - - Fascicular - - - - -	Composed of a peculiarly hard, elastic, insensible, parallel or interlaced fibre, very strong; which ossifies slightly in old age. Without proper action, but is extensible.	Gelatine ? - - 100	Water - - - - ? Common salts ? - 0.08
S. Periosteum, dura mater, sclerótica, albuginea, membrane proper to kidney, spleen: capsular ligaments, tendinous sheaths, aponeuroses. Tendons, ligaments.			

TABLE OF THE TISSUES OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
XII. FIBRO-CARTILAGINOUS. Membranous - - - - Articular - - - - - Tendinous sheaths - - S. Nose, trachea, palpebra, knee joint, lower jaw, articulation, periosteum, within tendinous sheaths.	Something between cartilage and ligament, having a base of parallel, or interlaced fibres, with cartilage interposed between them. Except the membranes, have no perichondrium; are rarely inflamed; elastic, pliable, insensible; re-unite slowly; no sympathies; slowly ossify in old age.	Coagul. albumen? 98.	Common salts - - 2.0 Water - - - - ?
XIII. MUSCULAR of animal life. Long - - - - - - Large - - - - - - Short - - - - - - S. Trunk and limbs, between skin and walls of cavities; or bones.	Red, massy, parallel, or diverging fibres; obedient to the will; contractile to a stimulus applied to themselves, to their *animal* nerves, or the brain; limited by antagonists; generally cross a joint; subject to fatigue; sympathise one with another; die with the lungs.	Fibrin - - - 17.7 Albumen - - 2.2 Gelatine? - - Osmazome - - 0.15 ——— 19.24	Phosph. Soda - 0.9[illegible] Phosph. Amm.? Phosph. lime - 0.08 Carb. lime? - - Mur. & lac. soda 0.18 Water - - - 77.17 ——— 78.33
XIV. MUSCULAR of organic life. S. Within walls of cavities.	Occupy the cavities; fibres pale, curved, or irregularly interlaced; never attached to bone, nor to fibrous organs. Form thin, flat membranes; rarely superimposed; not uniform; short; not obedient to the will; not symmetrical; not affected by stimulation of the nerves; receive their nerves chiefly from the sympathetic.	Same as XIII.	

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*		CHEMICAL COMPOSITION. *Saline.*	
XV. MUCOUS. Excreting - - - - - - Non-excreting? - or, *Gastro-pulmonary* - - *Genito-urinary* - - - S. Lining imperfect cavities; eye, nose, throat, pulmonary, alimentary, genital, urinary, passages. Facial sinuses, antrum, mammæ.	Soft, spongy, villous, equable membrane, furnished with follicles, glands, exhalants. Continuous with the skin, and lining all the cavities which open externally. Very sensible and irritable, though not contractile. Secretes mucus; pus when inflamed, but very rarely coagulable lymph. Scarcely ever forms adhesions or ossifications.	Gelatine - - - Mucus? - - -	100	Water - - - - - Common salts -	? 0.08
XVI. SEROUS. Locomotive - - - - - Fixed? - - - - - - - S. Lining imperfect cavities; thorax, abdomen, scrotum, head, labyrinth, eye, ovarium vesicle, blood and lymphatic vessels.	Dense, shining, semi-pellucid membrane, always forming a shut sac, and lining some shut cavity. Insensible, *irritable*, but not contractile; exhaling an albuminous fluid, named serum. Never continuous with other tissues; easily inflamed, when it pours out coagulable lymph, and adheres to part of its own sac; frequently ossifies, or forms hydropic collections.	Gelatine - - -	100	Water - - - - - Common salts -	? 0.08
XVII. SYNOVIAL. Articular - - - - - - Tendinous - - - - - - S. Lining joints. Tendinous sheaths, or bursæ mucosæ.	Shut sac; structural characters resembling *serous tissue*, but exhales synovia, a widely different secretion. Not affected in general dropsies, nor serous membranes in synovial dropsy; rarely and slowly adhere; of limited locomotion.	Gelatine - - -	100	Water - - - - - Common salts -	? 0.08

TABLE OF THE TISSUES OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*		CHEMICAL COMPOSITION. *Saline.*	
XVIII. GLANDULAR. Secreting - - - - - - - Aporous - - - - - - - S. Cavities, or the vicinity of cavities.	Insulated bodies, of indefinite form; rarely in pairs: of variable figure; easily torn; hardness increased, elasticity lost, by boiling.—*Have excretory ducts,* a parenchyma of variously organized cellular membrane; insensible?				
XIX. DERMOID. S. The surface of the body only.	Envelops whole body, originates the mucous system. The *corium,* or true skin, consists of fibres variously interlaced in layers, superimposed to each other, so as to form areas, which transmit the exhalation of sweat, the sebaceous secretion, and the pilous system. Embrowned by light, contracts by cold, convex towards the epidermis by boiling, and passes into gelatine. Elastic, enjoys the sense of touch, unites, when dead, with tannin.	Gelatine - - - Albumen? - - - Mucus? - - -	100	Water - - - - - Common salts - -	? 0.08
XX. EPIDERMOID. Of skin - - - - - - - Of mucous membrane - Of hairs? - - - - - - S. Surface of the body, mucous cavities, hairs?	Transparent, furrowed externally; separates from the skin by heat, vesicatories, putrefaction. Tinged yellow by nitric acid; brown by chlorine. Without fibres, inelastic, insensible; impregnated by water it becomes opaque; not crispable by heat; but forms an oil during combustion; abraded, it reproduces itself.	Coagul. albumen Mucus? - - - Gelatine? - - -	93.5	Common Salts - - Water - - - - - - -	0.08 ?

TABLE OF THE TISSUES OF THE HUMAN BODY, *Concluded.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
XXI. PILOUS. *Vibrissæ* - - - - - - *Cirrhi* - - - - - - - *Lanugo* - - - - - - - S. Head particularly, arm-pits, genitals, nose, caruncula lacrymalis, ears, diseased ovaria.	*Conical* prolongations from bulbs under the true skin. Semi-transparent; resoluble into cuticle, corpus mucosum, and parallel but unequal fibres. (Flem. Zool.) Slightly crisped by heat, insensible? hollow? made lighter by maceration; black, by lunar caustic; yellow, by nitric acid; brown, by chlorine; depolarize light.	Coagulated albumen, 94 Mucus? - - - - Gelatine? - - - - White concrete oil ? Greyish green oil, sometimes red, or black - - - - - - } ?	Sulphate of lime - } 1.5 Lactic acid - - - - } Lactate of potass - } Phosph. of potass } Muriate of potass } Magnesia - - - - - } Iron - - - - - - - - } Silica? - - - - - Sulphur - - - - Phos. & carb. lime - ? Phosphate of magnesia? Water - - - - - - ?

TABLE OF THE FLUIDS OF THE HUMAN BODY.

ALBUMINOUS, WATERY, MUCOUS, OILY.

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*		CHEMICAL COMPOSITION. *Saline.*	
I. *ALBUMINOUS.*					
I. Blood. Arterial - - - - - - - Venous - - - - - - -	S. G. 1052. Separates into fibrinous mass and serum, which last coagulates by heat 165° F.; colour red; but modified by nitre and gases; contains globules; heat 102°-4° F.; taste saline; feel slippy.	Albumen - -	77.01	Carb. acid - - -	?
		Fibrin - - -	11.33	Mur. Pot. & Sod.	5.80
		Colouring mat.	19.66	Lact. Soda - -	4.85
Situation. Pulmonary veins, bronchial veins? left side of the heart, arteries. Right heart, pulmonary artery, veins, menstrual secretion?		*Muco-extractive* -	?	with { Soda, and / Phos. Soda, }	3.20
		Animal matter -	?		
				Sulph. Potass. - -	?
			108.00	Water - -	877.00
					890.85
		GLOBULES.			
		Colouring mat.	987.50	Oxid iron - -	6.23
		Adipocire? - -		Sulphos. iron -	0.94
		Albumen? - -		Phos. lime & mag.	0.75
		Fibrin? - - -		Carb. lime? -	4.01
				Loss - - - -	0.56
			987.50		12.49

TABLE OF THE FLUIDS OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
II. CHYLE PROPER. S. Lacteals, thoracic duct, subclavian vein and superior cava, right auricle and ventricle, morbid urine.	S. G. White, sweet, coagulable, and separable into clot and serum: the latter coagulable by heat.	Fibrinous albumen - ? Albumen - - - ? Adipocire - - - ? Lactic sugar - - ?	Mur. Soda - - - ? Phosph. lime - - ? Common salts - - ? Water - - - - - ?
(II.) DUODENAL CHYLE. S. Small intestines.	Yellow, semi-transparent, bitter, weak odour, grey, if from fat. *M.*		
III. CHYME. S. Stomach, small intestine above, (and below?) gall ducts.	Pulpy, grey coloured, sweetish, insipid, slightly acid, pungent odour.		
IV. MILK. S. Female mammæ, blood? urine? male and fetal mammæ?	S. G. 1043. Boils and freezes nearly as water; white, sweetish, forms a cream, reddens blues, at length acidifies, separates into coagulum, and serum, or *whey.*	Butter - - - ? Casein - - - 28.0 Albumen - - - ? Lactic sugar - 35.0 Lactic acid - - 5.0 68.0	Mur. Potass - - 1.7 Phosph. Potass - 0.3 Phosph. lime, *m.* 0.3 Ac. Pot. & lact. iron 1.0 Water - - - 929.0 932.3

TABLE OF THE FLUIDS OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*	CHEMICAL COMPOSITION. *Saline.*
V. Serous Secretion. S. Brain, eye, ear, thorax, abdomen, scrotum ovarian vesicle.	Watery, saline, slippery; becomes opaque by heat of 165° F., and forms flocculi.	Albumen - - - 18	Mur. Soda - - - 2.0 Carb. Soda - - 1.0 Phosph. Lime - 1.0 Water - - - - 78.0 82.0
VI. Liquor Pericardii. S. Cavity of pericardium.	Extremely like serous secretion.	Albumen - - - 5.5 Mucus - - - - 2.0 7.5	Muriate Soda - - 2.0 Water - - - - 92.0 94.0
VII. Synovia. S. Joints, bursæ mucosæ.	Extremely viscid, slippery, semi-transparent, greenish white, peculiar smell; clots to a jelly, mixes with water, and froths, precipitated by alcohol and acetic acid.	Proper fibrous matter - - - - 12.0 Albumen - - 4.5 16.5	Mur. Soda - - - 1.7 Soda - - - - 0.7 Phosph. Lime - 0.7 Water - - - - 80.0 83.1
VIII. Liquor Amnii. S. Amnion of the fœtus; first passages of the fœtus?	S. G. 1006. Somewhat milky, mawkish odour, saltish taste; becomes transparent by filtration; reddens turnsol, but greens violets; opaque by heat.	Albumen - - 1	Mur. Soda, Soda, Phosph. Lime, Pure Lime - - 0.2 Water - - - - 98.8 99.0

TABLE OF THE FLUIDS OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*	CHEMICAL COMPOSITION. *Saline.*
IX. Liquor Ovuli Humani. S. Ovarian vesicle, semen mas?	Limpid sometimes reddish or yellow, coagulating into strong threads by alcohol, or heat.		
II. *WATERY.*			
X. Pulmonary Halitus. Situation. Pulmonary passages.	Limpid pure water, without any admixture whatever.	Pure water - - 100 *or*	Oxygen - - - 88.9 Hydrogen - - 11.1 100.0
XI. Cutaneous Exhalation. Perspiration - - - - Sweat - - - - - - - S. Skin.	Watery, inodorous, less pellucid than water; somewhat viscid; taste saltish, easily evaporates.	Oil - - - - - - Acid—Lactic, or Acetic, or Phosphoric?	Carbonic Acid - - ? Mur. Soda - - - ? Mur. Potass - - - ? Lact. Soda - - - ? Water - - - - - ? Phos. Lime - - - ?
XII. Urine. Of drink - - - - - - Of chyle - - - - - - S. Pelvis of kidney, ureter, bladder, urethra, urachus? stomach? skin? brain?	S. G. 1033. Transparent, amber-coloured, violet smell, taste, saline, bitter, disagreeable; cloud in the middle; when cool, smell urinous, fetid, reddens turnsol.	Urea - - - - 30.1 Uric Acid - - 1.0 Lactic Acid - 1.5 Lact. Ammonia } 17.0 Anim. mat. Alc. } Mucus of bladder 0.32 52.8	Sulph. Potass - 3.7 Sulph. Soda - - 3.16 Phos. Soda - - 3.0 Mur. Soda - - 4.4 Phos. Amm. - - 1.65 Mur. Amm. - - 1.50 Earthy Phosp. } 1.0 Fluate of Lime } Silica - - - 0.03 Water - - - 933.0 Carb. acid - - ? 949.34

TABLE OF THE FLUIDS OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
XIII. TEARS. S. Lacrymal canals; eye-ball, sac, nose, mouth?	Taste saline, aspect watery, no smell.	Mucus - - - - 1	Mur. Soda - - - Soda - - - - - - Phosph. Lime - Phosph. Soda - } 1.0 Water - - - 98.0 ——— 99.0
XIV. AQUEOUS HUMOUR. S. Anterior chamber of the eye.	S. G. 1009. Very watery, insipid, inodorous.	Albumen—*trace* - - Animal matters - W.	Mur. sod. & pot. Lacts. sod. & pot. } 2.0 Soda - - - - 0.75 Water - - - - 98.0 ——— 100.75
XV. VITREOUS HUMOUR. S. Posterior chamber of the eye.	Characters of aqueous humour but a little denser. S. G. 1009.	Albumen - - 0.16 Animal matter - W.? ——— 0.16	Murs. & lacts. - 1.4 Soda - - - - 0.2 Water - - - - 98.0 ——— 99.6
(XV.) LENS. S. Posterior chamber of the eye.	Transparent; scarcely fluid, fibrous, lamellated, consolidated by heat; densest in the centre, where S. G. 1194, in general 1100.	Peculiar matter - 35.9 Animal mat. Alc. ? Animal mat. W. ? Cell. mem. insol. 2.4 ——— 38.3	 *with* Murs. & lacts. - 2.4 *with* Phosphates - - 1.3 Water - - - 58.0 ——— 61.7

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
III. *MUCOUS FLUIDS.*			
XVI. MUCOUS SECRETION. Alimento–pulmonary, genito-urinary, mammary, membranes.	Like mucilage of gum arabic; somewhat opaque, absorbs oxygen, and becomes thick and quite opaque; adhesive when dried; does not dissolve in water; is precipitated by sub-acetate of lead.	Mucus - - - 53.3 Animal matter - 2.0 Albumen - - - ? Peculiar animal matter - - - } 3.5 58.8	Murs. Soda & Pot. 5.6 Lactate Soda - - 1.0 Soda - - - - 0.9 Phos. Soda - - ? Water, *say* - - 33.7 41.2
XVII. SALIVA. S. Salivary ducts, mouth, alimentary passage: Trachea?	S. G. 1016. Limpid, very viscid, insipid, inodorous; difficultly unites with water; absorbs oxygen, and thickens; deposits tartar, or salts of lime.	Animal matter - 3.0 Mucus - - - - 1.3 Albumen? - - 4.3	Murs. Pot. & Sod. 1.7 Lactate Soda - - 0.9 Soda - - - - - 2.0 Water - - - - 91.1 95.7
XVIII. PANCREATIC JUICE. S. Pancreatic duct; duodenum; large intestines in salivation?	Characters of saliva.	Supposed same as saliva.	
XIX. AMYGDALOID SECRETION. S. Tonsils.	Characters of mucus; but yellow, fetid.	Supposed same as XVI.	

TABLE OF THE FLUIDS OF THE HUMAN BODY, *Continued.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
XX. ARYTENOID SECRETION. S. Arytenoid glands.	Opaque, crass, yellow, very fetid.	———	———
XXI. BRONCHIAL SECRETION. Bronchial glands, morning expectoration.	Black or blue colour; insipid, inodorous, gelatinous, semi-transparent.	Mucus - - - ?	Carbon ? - - - - Water - - - - - ?
XXII. SEMEN. S. Testicles, vesiculæ seminales? vas deferens, urethra, bladder.	S. G. 1085. Fluid; milky aspect; contains a thick mucilaginous substance, with white shining filaments; odour peculiar, disagreeable; greens violets; liquefies in the open air.	Mucilage - - - 6.0 Animalcula - - ? ——— 6.0	Phosph. Lime - - 3 Soda - - - - - - 1 Water - - - - 90 ——— 94.0
XXIII. PROSTATIC LIQUOR. S. Prostate gland, urethra.	Resembles much the white of an egg?	———	———
XXIV. COWPERIAN SECRETION. S. Cowper's glands; urethra.	Characters of mucous secretion? colour slightly reddish.	———	———

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION.	
		Animal.	*Saline.*
IV. *OILY FLUIDS.*			
XXV. Fat. S. Spherical cells of the adipose membrane, renal region, omentum.	White, tasteless, inodorous; melts at 95° F. Contains stearin and elain; produces an intolerable smell in destructive distillation; 100 of alcohol dissolves 25 of its stearin.	Stearin - - - - ? Elain - - - - - ?	Salts - - - - - ?
XXVI. Medulla. S. Cavities of bones.	Yellow, or pure red; taste agreeable; no smell; melts 113° F.; distilled, it yields a white oil, not becoming black, as in fat; something between butter and oil.	Oil - - - - 96.0 Albumen, Gelatine, Extractive, Peculiar matter } 3.0 99.0	Phosph. Lime - - ? Carb. Lime - - - ? Soda - - - - - ? Water - - - - 1.0 1.0
XXVII. Cerumen. S. Meatus auditorius externus.	Viscid, orange yellow, bitter; heated, it melts, stains paper, emits an aromatic odour; and a white smoke like burning fat, nearly all soluble in alcohol, hardens in the air.	Albumen - - - - Inspissated Oil - - Colouring matter - -	Soda - - - - - - Phosph. Lime - - -
XXVIII. Cutaneous Serum. S. Sebaceous follicles of the skin.	Unctuous, inflammable, bland, tenacious, indurated by exposure to the air; taking the form of the follicle.	Probably similar to Cerumen.	

TABLE OF THE FLUIDS OF THE HUMAN BODY, *Concluded.*

NAME, DIVISION, SITUATION.	CHARACTERS.	CHEMICAL COMPOSITION. *Animal.*		CHEMICAL COMPOSITION. *Saline.*	
XXIX. SERUM ODORIFERUM. S. Corona glandis, clitoridis: mammæ.	Thick, dirty white, unctuous, inflammable, friable, subfetid.	Probably similar to Cerumen.			
XXX. MEIBOMIAN SECRETION. S. Eye-lids.	Thick, inodorous, insipid; becoming opaque in the air; viscid; slowly uniting with water.	Disputed whether oily or muçous.			
XXXI. BILE. S. Gall ducts, gall bladder, intestines, fæces.	Yellowish green; sometimes brown; unctuous, bitter, peculiar odour.—S. G. 1040.	Picromel - -	80.0	Soda - - - -	4.1
		Albumen - -	3.0	Mur. Soda - - -	3.4
		Erythrine? - - -		Phosph. Soda - -	1.0
		Resin? - - - -		Phosph. Lime - -	0.1
		Yellow matter? -		Iron? - - - -	
				Water - - -	908.4
			83.0		917.0

Dr. C. SMITH'S TABLE OF INFLAMMATIONS AND TISSUES,

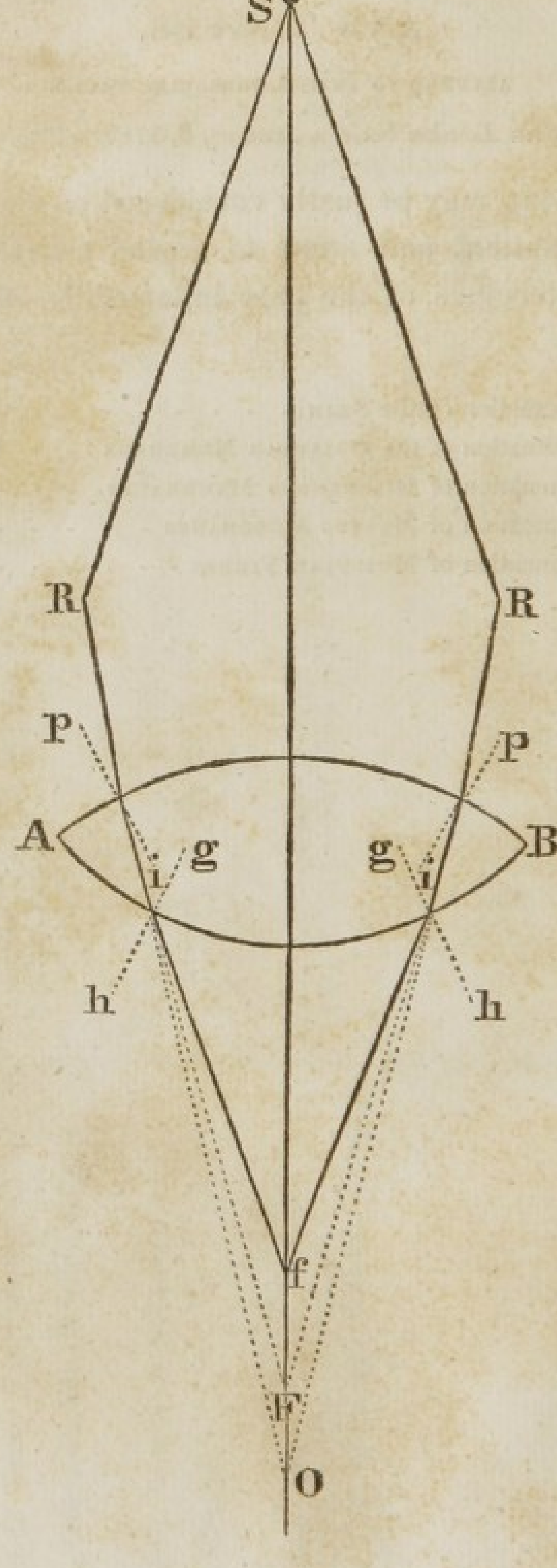
ALLUDED TO IN THE PRECEDING TABLE.

Read before the London Society, January 8, 1788.—*Published* 1790.

"The following may be justly considered as distinct species of inflammation, and seem to *depend entirely* upon the peculiar structure of the part inflamed."—*Med. Com.* II. 175.

I.	Inflammation of the Skin - - - - - - - - -	Erysipelas.
II.	Inflammation of the Cellular Membrane - -	Phlegmon.
III.	Inflammation of Diaphanous Membranes - -	———
IV.	Inflammation of Mucous Membranes - - - -	———
V.	Inflammation of Muscular Fibres - - - - -	———

Demonstration of the manner in which the convergency of the rays of light is INCREASED *by passing through the vitreous humour.*



APPENDIX.

[The following demonstration of the manner in which the convergency of the rays of light is increased by passing through the vitreous humour, will be read with satisfaction by those who have lately seen assertions that the office of this humour was to produce the contrary effect.]

The following question has been proposed :—The rays of light, which proceed from an object and pass through the eye, fall upon the vitreous humour in a convergent state ; is that convergency increased or diminished by the refractive power of the vitreous humour, which being a rarer medium than the crystalline, the rays, in passing through it, are subject to the fundamental law of Dioptrics, viz. When a ray of light passes obliquely out of a denser medium into a rarer, it is refracted *from* the perpendicular ?

To answer this question satisfactorily, all that is required is to trace the progress of a pencil of rays through the eye, according to the laws of refraction ; but the form and effect of the crystalline humour being like those of a double convex lens, it is clear that the same result will be produced by tracing the passage of rays through such a lens, into the air, which being a rarer medium, may conveniently represent the vitreous humour.

Suppose then A B to represent a double convex lens ; S a point of a distant object situated directly before the lens ; the ray S f F O passing from S through the lens perpendicular to the spherical surfaces, will proceed without refraction or deviation from its rectilinear course, and in the eye would form the optic axis. The rays R, R, also coming from S, are supposed to have fallen on the cornea somewhat divergent, but by the refractive power of the cornea and aqueous humour to have become convergent, in which state they are here represented falling on the anterior surface of the lens. Entering now a denser medium, they are refracted or bent *towards* the perpendiculars p i, p i, (radii to the convex surface at the points of incidence) by which they are made to fall more converging on the posterior surface of the lens. If they were now to proceed through the rarer medium, without any further refraction, they would meet at the point F of the axis, but being refracted *farther from* the perpendiculars g h, g h, (perpendicular both to the surface of the lens and the concave surface of the rarer medium) which have directions contrary to the directions of the perpendiculars p i, p i, the rays must continue to approach each other, and will meet at some point f of the axis, which being *nearer to the lens* than the point F, where they tended to unite previous to their entrance into the rarer medium, it is evident that *their convergency has been increased.*

It has been shown, that if the crystalline and vitreous humours had the same refractive power, the rays R, R would be refracted to F ; but if the vitreous be the rarer medium, they will converge to f, thereby becoming more convergent. If, on the contrary, the vitreous humour had a greater refractive power, or was more dense than the crystalline, then the rays entering it from the latter would have their *convergency diminished*, because they would be refracted *towards* the perpendiculars g h, g h, and consequently would not meet on the axis until they arrived at some point O, further from the lens than F. So that the increase of convergence which the rays acquire in moving through the vitreous humour, is solely and entirely owing to it being a rarer medium than the crystalline, combined with its concave surface.

And it may be added, that each of the humours of the eye, by its peculiar form and density, contributes to cause a convergence of the rays ;—the aqueous from its convex form ; the crystalline by its double convexity and greater density than the aqueous ; and the vitreous by a less density than the crystalline joined to its concave form.

Physiology of Vision.

THE following extract, translated from the Latin of DR. G. M. BERRUTI'S Paper, on Light and Vision,* will be read with interest, as containing a well-digested summary of the best established doctrines relative to the Physiology of the Eye.

——The refractive power of the cornea and humours of the eye, although examined in various methods by different persons, has been stated by all nearly in the same way. When light passes from the air into the aqueous humour, the sine of incidence to that of refraction, is nearly 4:3, according to the general conclusion; the refracting power of the cornea, not often being computed by opticians, on account of the thinness of this membrane. But light, in passing from the aqueous humour into the crystalline lens, makes the sine of incidence to the sine of refraction, according to Jurin, :: 13 : 12; according to Hawksby, :: 11 : $10\frac{2126}{1000000}$; according to Porterfield, ::87:85, and vice versa from the crystalline into the vitreous humour. Chaussat defines, by the most ingenious experiments, the sines of incidence to that of refraction, when light passes from the air to the various media of the eye, by the following numbers; with respect to the cornea 1,33 : to the aqueous humour 1,338 : to the lens and its exterior strata 1,338 : to its nucleus 1,420 : to the vitreous humour 1,339.

It is certainly more difficult to determine the convexities of the cornea and crystalline lens, than to correctly define the aberrations of sphericity to which the rays of light must be subjected while passing through the various media of the eye; for not only do we find a difference of convexity in various species of animals, but even in the same species, at different ages, climates, and under other accidents. Yet, if the motion of the pupil, the position of the iris, its use, as well as that of the black pigment, may enable us to decide, it may be understood, as we shall see below, how light dispersed by aberration of sphericity is retained, lest by reaching the retina it should disturb vision.

In relation to the achromatic power of the eye, whatever may be said by some, it is very far from being thoroughly proved; the achromatic lenses hitherto constructed, differ very much from the structure of the eye, as Garbi has observed. No one has ever defined the power by which each of the humours of the eye disperse the light—nor can any one observe this dispersion. Besides, no one can say that this achromatic power is at all necessary to vision: for it is known that the dispersion of light does not affect our eyes, unless the light passes a determined space in the body, which certainly exceeds that existing between the cornea and the retina. Wherefore it is possible that the eyes disperse the light, but vision is not therefore disturbed.

The rays of light sent from a lucid or illuminated body, either fall on the sclerotica, and are thrown off without entering the eye, or fall on the cornea and pass through it, moving according to their differences of obliquity.—One of the rays falling perpendicularly on the cornea, passes directly and without refraction through the aqueous humour, the crystalline lens, and the vitreous humour, till it reaches the retina. Hence it is called the *optic axis*. The other rays of light falling on the cornea, are distinctly perceived within an angle of forty-five degrees from the axis, and when this angle is taken on both sides of it, the right exhibits the field of vision. These rays, passing through the cornea, converge, or become less divergent, and approach the optic axis.

This convergence of the rays is continued through the aqueous humour and crystalline lens, according to the laws of refraction belonging to these parts; and hence it happens that not only the parallel rays enter the pupil, but also others, that without refraction could not enter, on account of their obliquity. But the more lateral and oblique rays, falling on the iris, are again reflected outwards, or are absorbed by the black pigment, and thus it happens that those rays alone arrive at the lens, which are strongest near the perpendicular line, and can enter together.

* Published at Turin, 1823.

Yet all the rays that arrive at the lens do not pass through it; for some are even then reflected and absorbed by the black pigment. But the others, which penetrate the lens perpendicularly, pass on, not by describing a straight, but a curved line, to define which it becomes necessary to consider the differences between the refracting powers of the exterior and interior strata, and the difference between the anterior and posterior convexity of the lens. If Monro, and almost all the mathematicians be correct, the vitreous humour possesses a less refracting power than the crystalline lens, and hence the light passing from the one to the other, ought to depart from the perpendicular; but if we may believe Chaussat, the contrary rather happens: in either case, the deflection of light is so small as scarcely to merit consideration, and may be said to pass from the lens to the retina in a right line.

All the rays sent from the different points of an object, retain the image of the point whence they are emitted, and depict it on the retina, and thus when all the rays emitted by any object fall together on the bottom of the eye, they paint a correct image of the object, although it is inverted on account of the necessary decussation of the rays. That such is the fact, may be easily demonstrated by experiment. If the sclerotic and choroid coat be removed from the posterior part of the eye of an ox recently killed, the inverted images of external objects will be seen depicted on the retina. Magendie has observed this circumstance in the eyes of albinos, or animals having translucent sclerotic and choroid coats.

It is therefore not the crystalline humour, as the ancients, with the exception of Halazen and Vitellianus, commonly thought; nor the choroid, as Mariotti, Thery, Mayran, Lecat, and others have imagined, are the principal organs of vision, but the retina; that is, the part of the eye which receives the impressions of light, and by the agency of the optic nerve carries the impression to the common sensorium, that vision is excited.

When the eye is properly formed, the rays of light pass into the eye in the manner stated; but if the cornea is more convex, if the quantity or density of the humours of the eye are increased, if the crystalline is harder, or its anterior part more prominent, then the rays of light are more refracted, and converge to a focus before they reach the retina. This defect is peculiar to those who see none but the nearest objects distinctly, and is called *myopia*;—it is common to infants; and is usually corrected by the use of concave glasses, which cause the light to diverge. The opposite to this condition is produced by the flattening of the cornea or the anterior surface of the crystalline—in proportion to the want of density in this humour, or the quantity of the other humours, the rays are the less refracted, and the focus is formed at too great a distance. In this condition, called *presbyopia*, only distant objects can be seen: it usually exists in old persons, and is corrected by convex glasses. If the pupil, from some morbid affection, becomes too much dilated, and does not contract; if the retina is more irritable or too sensitive, vision will necessarily be injured by meridian or too vivid light; but in the evening, when only so many rays are received as are sufficient for vision, the sight is perfect. This defect is called *nyctalopia;* the opposite state, arising from opposite causes, is called *hemeralopia.*

The following circumstances are necessary to correct vision; 1st, perfect *union* of the rays on the retina; 2d, natural sensibility of this membrane, and of the optic nerve; 3d, a correspondence between the quantity of light and the sensibility of the retina. It is impossible to understand how the rays so constantly coalesce on the retina, whether from near or distant objects, unless it is admitted that the eyes are subjected to changes, in the various accidents peculiar to vision. Authors have differed much on this point. That opinion seems to come nearer the truth, which attributes the greatest part of this effect to the motions of the pupil; as it is well known that the pupil not only dilates in the dark, but also in examining remote objects, and is contracted in scrutinizing small bodies, no less than in a strong light, and in making most accurate examinations. It is also known, that the most perfect images of external objects are obtained by the camera obscura, (which exhibits a resemblance to the eye,) when the size of the opening is suited to the distance of objects—enlarged if the objects are more remote, or contracted if they are nearer. Besides the pupils, the motions of the cornea have some purpose in producing distinct vision; since its convexity may be changed when contemplating near or distant objects, as has been proved by Home. This change of convexity is proved by the muscles moving the eye, as is manifest in the eyes of birds: for it is equally necessary in them in viewing near or distant objects, that their eyes should be subject to greater mutations: for this purpose, Nature has furnished their corneæ with an osseous circle, by which the muscles of the eye can act with greater power, and increase the convexity. In man, when the limits of distinct vision are less extensive, the motions of the pupil generally suffice for objects at different distances, and the cornea is only changed in figure when objects are to be viewed at the greatest distances.

It is very difficult to determine the limits of distinct vision, for these partly depend on the conformation and sensibility of the eye, and partly on exercise;—nor is it uncommon to observe in the same person a difference of power in this respect between both eyes. Vision is generally said to be perfect, when the eye sees with equal distinctness and clearness, objects at eight inches distant and those more remote. The greatest distance at which solitary objects, illuminated by a bright sun, can be distinctly seen, is that which is properly 6700 times larger in diameter, so that a solitary object can no longer be plainly seen, when its optic angle is equal to thirty degrees. Tobias Mayer states, that the boundary of distinct vision is in the subtriplicate ratio of the distances, or as the cube root of the distance, or inversely as the sixth root of the brightness of the object.

From these circumstances, the great utility of the motions of the pupil is made evident: in consequence of these the rays of light most constantly fall together on the retina—by these the quantity of light admitted is always regulated, and in a weaker light, or when the sensibility of the retina is diminished, the rays are admitted in sufficient quantity to the retina. It is still disputed as to the cause whence these motions depend.—Some believe them to be voluntary, because in some animals they are manifestly subjected to the will, as in the parrot, noctua, and ray; but it does not seem sufficiently accurate, from observation of these animals, to conclude, that the same occurs in man. Bellingeri has pointed out, that in the animals mentioned there is no ophthalmic ganglion, which would serve to hinder the mandates of the will from arriving at the iris. But it is easily proved by observation, that the motions of the pupil depend on the affection of the retina, and that it is never in our power to move the pupil, when the same object is beheld at the same distance, in the same degree of light. If the contrary has sometimes happened in man, as Mascagni asserts relative to Fontana, it is at least probable in these cases, either that the ophthalmic ganglion is entirely deficient, as Gunzius has observed, or some nervous filaments have gone directly to the iris; but there is no branch from the ophthalmic ganglion, nor from the ganglion constituting the ciliary circle, that undergoes any modifications by which it can be so far rendered obedient to the will as to be separated from the ganglion. The same may be asserted of the common fowl, whose iris Bellingeri has observed to be partly voluntary. Some admit muscular fibres in the iris, from which they deduce the motion of the pupils. But there is much difference of opinion on this subject; some physiologists believing that there is a double musculous stratum in the iris, one anterior and circular, the other posterior and radiated.—The iris being closed by the contraction of the circular fibres, and dilated by the action of the radiated fibres. Demours rejects the posterior fibres, and only admits the anterior; and Zinn and Le Roy deny the orbicular fibres, and only admit the orbicular. But all those who have examined the iris, without any preconception, agree that they saw no muscular fibres; moreover, the experiments of Fontana and Magendie prove that the iris may be injured in any manner without producing any sign of irritability or showing any motion. At the same time it is moved immediately if the retina is disturbed; therefore, the motions of the pupil do not depend on the irritation of the iris, but on the affection of the retina. It therefore seems more correct that some physiologists have thought the motions of the pupil depend on a kind of vital turgescence, excited by the consent of the iris with the retina, and Professor Rolands thinks the vascular excitement of the iris is produced by the affection of the retina.

The manner in which this consent is effected is not decided. Some think it dependent on the brain itself, yet as the motions of the iris are involuntary, the involuntary motions are not governed by the brain; besides, in amaurosis, there is no direct communication between the retina and cerebrum, yet the motions of the iris depending on the consent of the retina, remain still very vivid. Sprengel, in explanation of this phenomenon, places an antithesis between the optic and ciliary nerves, for he says another and fitter connexion of either system does not exist. While I do not think it sufficiently proved that there is an antithesis of the nerves, in the manner admitted by the friends of the doctrine of polarity, I think at the same time it cannot be asserted that there is no other connexion between the retina and iris. I may mention the central artery of the retina and the ciliary arteries are branches of the same trunk of the ophthalmic artery, and necessarily have the same nerves, and go both to the retina and iris; Chaussier and Ribes have observed a fasciculus to arise from the great sympathetic, where it surrounds the carotid, which accompanies the ophthalmic artery and all its branches, so that it reaches both the retina and iris. I may moreover mention these circumstances by which some think that the consent of the iris and retina may be explained. I will observe, that Bellingeri believes the consent of the retina with the iris is to be sought in the intimate connexion of the ciliary nerves, the ophthalmic ganglion, and the nasal branches, with the sheath of the optic nerve. It appears possible to explain this consent in another twofold manner, for we observe that the nervous filaments arise from the ganglions constituting the ciliary circle, some of which go to the iris, and others to the ciliary processes, reaching to the anterior extremity of the retina. May it not be suspected, that the ganglion composing the ciliary circle may be intended to preserve the consent between the iris and retina? In fishes having no ciliary circle, Cuvier has observed that there are none or scarcely any motions of the pupil. The ophthalmic ganglion (formed by a branch of the third pair, by a branch of the nasal of the fifth, and by some filaments of the great sympathetic, as has been demonstrated by Chaussier, Ribes, and especially Bock,) besides the ciliary nerves, also give the branch mentioned by Ribes and Chaussier, which accompanies the central artery of the retina. What purpose does this branch serve, unless it is to connect the iris with the retina? May we not in the same way explain the clouding of the sight, and the dilatation of the pupil, that happen on section of the cervical portion of the great sympathetic, or from great intestinal irritation? May we not by the same means, no less than by the above mentioned nerves, easily understand why the dilatation and immobility of the pupil are frequently wanting in amaurosis; or why in these cases the pupil is more contracted, and the iris contracts on the admission of the least light, while on the other hand the dilatation and immobility may occur, though the amaurosis be great. The following considerations will explain the circumstance.

Light appears to act in a twofold manner on the retina, first as a privative stimulus fit to excite vision, and as a stimulus in the ordinary sense of the term. The first mode of action is conveyed to the common sensory by the aid of the optic nerves, for the production of vision; the other mode of action is either produced through the nerves which arise from the ganglion of the ciliary circle, or, by aid of the filament which arises from the ophthalmic ganglion, may be propagated to the iris and effect its motions. From these positions we easily explain why the motions of the pupils sometimes take place and are sometimes absent in amaurosis; for if the amaurosis depends on the affection of the optic nerve alone, and be not sufficient to destroy all the organic sensibility, in this case the amaurosis will be joined with mobility of the pupil; but if the amaurosis depend on a violent affection of the retina, or even of the optic nerve, and be so great as to destroy the animal and organic sensibility of the retina, the amaurosis will be joined with immobility of the pupil. In the same manner it may be easily understood why the pupil is sometimes immoveable without amaurosis; as it may be produced by the slightest lesion of the nerves forming a communication between the retina and iris.

From all that has been stated, it is shown that it arises from the peculiar action of light on the retina, which by the optic nerves is conveyed to the brain, the seat of the common sensory. But why is it, when the same object is depicted on both eyes, and a double sensation hence produced, that the object appears single. Some persons are of opinion we see all things double with both eyes; and experience alone enables us to correct our judgment: but the man born blind, who was restored to sight by Cheselden, did not see any object double, but single, though he used both eyes, which were not taught by experience. Others, though on what foundation is not stated, think that we see a body with one eye alone. Does not daily experience teach us that the same objects always seem larger to both eyes than to one? Some physiologists say, in explanation of this phenomenon, that the images of objects unite together, where the nerves are joined together; but in the case mentioned by Vesalius, where there was no junction of the nerves, the sight was never double;—besides, what are we to say of drunkards, and those who squint, whose optic nerves are joined like other men, and yet see all objects double; if we press on the eye with the finger, the union of the nerves is not affected, yet objects seem doubled.

These and similar theories were advanced by physiologists in explanation of these phenomena, until Reid, Stewart, and others, showed that ideas were not excited by the contemplation of external objects, but only from a peculiar impression, carried in an unknown manner to the common sensory. Wherefore, when the retina of both eyes possessed the same susceptibility, if at the same time and manner both eyes were affected, none but impressions in unison would be carried to the sensorium, to excite a single idea in the mind, which would be the more vivid when coming from an affection of both eyes, than that depending on an affection of a single eye, though it would not be double. The same happens in sound affecting both ears—in odours affecting both nostrils, which do not excite an idea of double sound or odour. If in any manner the concord between both retinæ is interrupted, *diplopia* or double vision is immediately produced. This may be observed not only when the axes of the eyes are not parallel, as happens in *strabismus*, but also when either eye is affected by inflammation, or is more sensitive than the other. In the same manner we explain readily why bodies are seen in their natural situation, while their images are inverted on the retina, though we are told that we are taught the natural situation of things by the touch. But neither the persons cured of cataract by Cheselden, Grant, Varo, nor by Everard Home, ever saw objects inverted, though untaught by experience. The mind is excited to vision, not by the image depicted on the retina, but by an impression carried to the common sensorium by the optic nerves.

It is more difficult to explain how the mind judges of the place, distance, and size of objects. It is generally stated that the size of a body is determined by the angle formed by the rays drawn from the extreme parts of objects to the cornea, and in fact this angle, called the optic angle, is greater or less according to the size of the object, if the objects are at the same distance from the eye; but if the same object be placed at different distances from the eye, then the optic angle is inversely as the distance, and objects will appear smaller in the ratio of their distance. But I ask what informs the mind of the magnitude of the angle? The vertex of any angle is a point, and the angle should therefore produce the same sensation whether larger or smaller. The size of the surface of the retina, touched by the rays emanating from bodies, seems to be better suited to excite an idea of their size, together with the intensity with which these rays affect the retinæ. Decisions founded only on such reasonings are however often fallacious, and therefore ratiocination is also to be resorted to. The mind judges of the magnitude of things not only by the manner in which the retina is affected, but also from the manner in which it is accustomed to be affected by given objects, and by comparing the size of known with unknown objects, or by attending to their distances. Thus when we see a man at the distance of a thousand feet, although his image is depicted extremely small on the retina, yet the mind judges him to be of the size of an ordinary man; but it not only judges the man to be greater than could be inferred from the picture on the retina, but also by comparing the surrounding objects with the known size of the man, they are known to be larger than they appear. If many objects are depicted on the retina at the same angle, those will be thought larger that appear to be farthest off. It appears that in the earliest periods of life, the inexperienced mind judges of the size of things solely from the size of the image on the retina. Thus Condorcet says that he remembers the time when objects appeared to him smaller in proportion to their distance, so that if he considered an ox at the greatest distance, it appeared to him to be an animal of the smallest size.

The mind cannot judge by the aid of sight of the distances of objects when inexperienced: if a blind man obtains his sight, all objects seem to touch his eye: but the mind is able to measure the distances of objects, 1st, from the angle formed by the two concurring optic axes; hence it is explained why those who have both eyes sound can in a manner measure the distances of objects with a single eye, why the greatest distances cannot be judged by the eye, for the angles at the greatest distances can scarcely be discriminated. 2d, by comparing the apparent magnitude of known things with their true magnitude. Thus if we observe a man and a tower at any distance, and observe the apparent magnitude of the tower to be nearly the same as that of the man, we should say that the distance of the tower is much greater than that of the man. 3d, From the confusion of the objects, which appear so in proportion to their remoteness. 4th, From the greater or less intensity of light sent from the object to the eye, for the greater the light is, the nearer the object, and the contrary. If the rising sun and moon appear larger and at a greater distance than at meridian, it is because their light, which comes to us from the horizon, is much weakened by the intervening vapour: this weakening of light we conceive to be owing to distance, and hence what we think to be more distant is thought to be larger. Painters, to express distant objects, do it by intensity of colour alone.

The place of an object, if we see it with both eyes, is the point in which the two lines drawn from the retina to the object mutually intersect each other. If we see it with one eye only, it is in the line which would be comprehended between two right lines, drawn from the retina to the edges of the object.

We perceive the motions of bodies in a triple manner; 1st, from the motion of the image on the retina; 2d, from the necessary circumvolution of the eyes, that we may see the body placed in various situations; 3d, by comparing the body that moves with the intermediate bodies from which it is removed, or to which it approaches. From this it appears, that we have not always a correct idea of the motion of bodies. Thus the retina has the faculty of retaining an impression received, for some time; whence, if a body is rapidly moved before our eyes, we attribute to it a figure and magnitude it has not, and suppose it standing still. This may be seen when a burning coal is whirled in a circle. If two bodies unequally distant from the eye, describe in the same time parallel and equal spaces, the most distant will appear to move slower than the nearer one; as the most distant space seems less than the nearer. If the distance at which a body is seen, is the greatest, so that the angle subtending the space may be passed over in a second, be only done in fifteen or twenty seconds, then the moving body appears to stand still, as happens with the planets, for the situation of the image on the retina is imperceptibly changed. If also the bodies and the eye are moved together in the same direction, no motion is perceived, the image on the retina not being changed. Thus in sailing we do not perceive the passage of the ship, but if we look on a fixed point out of the ship, they then change their place on the retina, and we believe them to move, though in a direction contrary to the course of the vessel. Θ

Experiments on a few controverted points respecting the Physiology of Generation. By JAMES BLUNDELL, M. D. *Lecturer, in conjunction with Dr. Haighton, on Physiology and Midwifery, at Guy's Hospital.*

AMONG the various questions which have been raised respecting the generation of animals, there is one, as yet undecided, which has not perhaps been hitherto investigated with all the care it deserves. It may be demonstrated by experiment, that, in this curious process, the male furnishes the semen, and the female the rudiments; but whether these two substances must have access to each other, in order that the young animal may be formed, is a question which still admits of dispute. It is true, indeed, that many naturalists have *asserted*, that contact is necessary; and Spallanzani has even gone so far as to demonstrate that it certainly takes place in the generation of the frog and toad. Still, however, notwithstanding the labours of physiologists hitherto, we are not, I believe, as yet in possession of any regular system of experiments, which proves that the semen must have access to the rudiments, in those forms of brute generation which most nearly resemble our own. In the present state of our knowledge, the reverse of this position seems, at least, not improbable, as the experiments of Dr. Haighton, a valued relative of mine, have shown, that evidences of generation may be produced in the ovaries, although the semen has been excluded previously to sexual intercourse by the closure of the Fallopian tube.

The principal object of the memoir, which I have now the honour of presenting to the Medico-Chirurgical Society, is to contribute some little towards the supply of this defect. In it I have endeavoured to show, that the semen must have access to the rudiments, in order that the young animal may be produced; and yet, that generation, although these approaches are necessary for its completion, may, to a certain extent, be accomplished without them.

As the rabbit was the animal, on account of its natural aptitudes, selected for my experiments, it may be proper, perhaps, before I enter on the recital of them, to premise a few remarks on its genital system.* In the Fallopian tubes, and ovaries, and, I may add, the *external* genitals of the doe, there is little, when we view the organs as they are suspended in the glass, to attract the attention of the observer. It is different, however, with the vagina and the wombs; these are so strongly contrasted with the corresponding parts of the human organs, the wombs, by their tubular form, and the vagina by its length, its laxity, and large diameter, that they cannot be overlooked.

The vagina, when full grown, is about four inches long, and so capacious that, without much stretching, it will readily admit the extremity of the fore-finger. Its size, indeed, is so considerable, that it makes an approach to that of the human vagina, and greatly exceeds the dimensions of the same canal in a moderate-sized monkey, preserved in the obstetric museum, at Guy's Hospital.

The wombs, the structure of which is scarcely less remarkable than that of the vagina, are two tubular organs, when unimpregnated, about three inches and a half long and about two lines and a half in their diameter; they are therefore, it is obvious, very unlike the human uterus, and rather resemble that of several of our domesticated animals, as the cat, for instance, the bitch, and the females of the rat and mouse tribe. These two wombs, it should be further remarked, communicate with the vagina by two distinct orifices; and they are so completely independent of each other, that the one may be removed without injury to the other, except a slight and superficial wound of that part where their necks lie in contact, and cohere.

Both the wombs and the vagina are, in these animals, furnished with longitudinal and annular fibres of a muscular structure, similar in kind to those of the intestines, but grosser and more distinct. In addition to these, along the inner margin of the wombs, from one extremity to the other, there runs a broad strip of fleshy fibres, which may, perhaps, not improperly be denominated the meso-

* It is scarcely necessary to remark that this description is not addressed to those who have made a study of comparative anatomy.

metric. I give the muscle this name, because it covers no inconsiderable portion of what may be called the *mesometry;** a delicate double membrane, the production of the peritoneum, which performing, for the tubular wombs, the office of a mesentery, unites them, like the intestines, to the chine. It is allied to the broad ligaments of the human womb.

All these fleshy fibres are animated with a very lively irritability. The mesometric muscle† changes the situation of the wombs. The wombs themselves perform a peristaltic action. The vagina not only performs this action, but an additional movement, which I shall hereafter have occasion to describe.

Such are the most striking characteristics of the genital system in the rabbit, those, at least, which the following experiments require me to notice. I may now proceed to the experiments themselves.

The first set of experiments was instituted with a view of ascertaining whether the semen and rudiments must have access to each other, in order that the young animal may be formed. For this purpose, an incision was made into the cavity of the belly, immediately above the wombs; and these, together with the upper part of the vagina, were pushed through the opening. One of the wombs was then divided near its mouth, in a transverse direction, (just as a piece of intestine might be), so as to separate it into two portions, the superior and inferior; or, as they may be designated from the annexed parts, the vaginal and Fallopian. After this division the organs were immediately replaced, and the wound was sewed up.

Notwithstanding this violence, in the course of a few days, or a few weeks at farthest, most of the rabbits recovered their health, and at different intervals became fit for the approaches of the male. But though the general health was restored, the recovery was not complete. The operation, as subsequent dissection proved, had the effect of interrupting the canal of the womb, its tubular cavity growing up at the line of division, so that the communication between the vaginal and Fallopian pieces became intercepted, and the semen and the rudiments could have no access to each other.

In this condition of the genitals, as soon as the sexual ardour was rekindled, the animals were submitted to the male; and, excepting in one or two anomalous instances, out of ten or twelve experiments, they all became pregnant from the *first* admissions. At different periods from impregnation the sexual organs were examined after death with great care and deliberation, when young animals were invariably found in the sound womb, but none in the interrupted. This, it is true, like the human uterus in extra-uterine pregnancy, was in many instances enlarged and developed and plentifully supplied with blood, indeed it often appeared as well adapted as its fellow for receiving and cherishing the rudiments; but with all its aptitudes for generation, it lay under one capital defect, its canal was interrupted; it intercepted the access of the semen to the rudiments, and without this access generation could not be accomplished.

To confirm this conclusion, the accuracy of which I doubted at the time, it was determined to submit it to the test of another train of experiments. In these it was my object, to preserve the principle of the preceding operation, the exclusion of the semen from the rudiments; and yet at the same time, to vary its circumstances as much as possible, in order to ascertain how far they had affected the result; for I need not observe, that circumstances often exert a silent and most fallacious influence over our experiments, (our negative experiments especially) to be deprecated the more, because, from its insidious nature, it is so frequently overlooked.

In this second series of experiments, therefore, instead of operating upon rabbits that were full grown, I made use of those only that were under their puberty; and instead of interrupting, as before, the canal of the *Uterus*, I interrupted that of the *Vagina*.

The vagina of the doe, it has been already observed, is at least three inches

* I venture on the name with diffidence, but no preferable term occurs to me; its etymology is obvious, and, I believe, legitimate and analogical.

† Is this muscle allied in function to the round ligaments of the human womb?

in length; so that although it is interrupted at the uterine extremity, there still remains sufficient room for the male organ. Of this peculiarity I availed myself, in conducting these experiments; and instead of cutting the uterus, I cut the vagina asunder, (near to the mouth of the womb) so as completely to interrupt its canal. In other respects the experiment was conducted as before.

This operation proved dangerous; much more so than the former; a number of the rabbits however recovered, and admitted, without repugnance, the approaches of the male. The result was decisive. Although the external genitals of these animals were turgid with blood, and the sexual excitement of some was remarkably lively; although too, in some of them, intercourse was renewed at intervals of a week or a fortnight, on the whole, as many as twenty or thirty times, not one became pregnant. Desire itself, in one or two instances, seemed almost insatiable; and in the rest, though suspended by coition for a time, in the course of a few hours, or a few days at farthest, it invariably recurred.

The same general appearances were observed, on dissection, in them all. The vagina, if the operation had been properly performed, was completely interrupted. In both the ovaries there were *corpora lutea.* In some cases, the wombs appeared to have undergone little change; in others, they were enlarged, and evolved as completely as in actual pregnancy; but in no one instance was there the appearance of a single *ovum,* extra-uterine or in the womb. In these, as in the preceding experiments, though in a different manner, the access of the semen to the rudiments had been intercepted, and under these circumstances, notwithstanding repeated commerce with the male, the formation of the young animal could not be accomplished.

In performing the experiments recorded in the preceding paragraphs, there are various little niceties in the mode of operating, the observance of which is necessary to ensure success. The incision which is carried through the abdominal coverings, may be made in the linea alba, and should be eight or ten lines, at least, in length, in order that the parts may be replaced with facility. It should, too, lie as close to the *symphysis pubis* as possible, that the intestines, which in this herbivorous animal are numerous and cumbersome, may not, as they are apt to do when the incision is higher, protrude at the opening. It is true, indeed, that if the incision is placed in the vicinity of the pubes, the bladder, when it is distended, will fall in the way; but if the operator possess the requisite dexterity, there is no danger of wounding it; and a gentle pressure, persevered in for a time, will occasion it to withdraw into the pelvis. It deserves remark, however, that to produce this contraction, a little perseverance is necessary; for the bladder is not, in this manner, so readily excited to contract, as from previous reasonings on its irritability, we might have been led to expect.

To close the abdominal opening, the Glover's suture will serve as well as any other; nor does the including the peritoneum in the stitches, so far as I have been able to observe, materially increase the risk of a general inflammation. Exemption from this, depends much more upon the habit of the animal, than the niceties of the wound.

And here I may be permitted to remark, in the way of digression, that from various observations* upon brutes, as well as my fellow-creatures, I cannot forbear imagining, that the risk of extensive inflammation, from local injury of the *peritoneum,* has been exaggerated, perhaps greatly. The high importance of this principle in surgery, is too obvious to require a comment; already a sufficient number of observations has been accumulated, to induce us to examine it with attention; and I may add, that it is one of those grand practical points, which ought not to be decided by a few casual facts, much less by authorities, however venerable; but, like every other principle of a solid philosophy, by various, deliberate, and unbiassed experiment and observation.

If in performing this operation, (as in the first set of experiments,) the womb

* Operations for hernia and on the abdominal viscera of rabbits and dogs. The rabbit I suspect is very liable to spontaneous inflammation of the bowels. I have known in women the malignant ulcer of the womb penetrate into the peritoneal cavity, between the *rectum* and the *uterus,* without exciting a general inflammation of the belly.

is divided, the incision should be made transversely near its mouth, in order that we may leave the Fallopian piece as large as possible, for the reception of the *ova*, in case the genitals should have power to form them. It ought, too, to be carried from four to six lines into the mesometry, in order that the pieces thus liberated, and moving out of apposition with each other, may not reunite so as to form anew a continuous canal. If, on the contrary, (as in the second scheme of experiments,) the vagina is divided, a ligature should be applied to the orifice of that piece of it which remains annexed to the womb, and fastened to the margin of the external wound. This precaution ensures the escape of the thread,* and at the same time prevents the pieces of the vagina from falling into apposition, and renewing the continuity of the canal.

When the genitals are mature, the rabbit very frequently dies from this operation, which, in consequence of the large size of the vagina, is more violent than the former. It is better, therefore, on this account, as well as for reasons already assigned, to operate before puberty. Previously to this change the parts are comparatively small, and the interruption of the vagina does not, as we might have been led from previous reasonings to expect, prevent the subsequent developement of the sexual organs. But to return from these details.

Although it appears probable, from the preceding experiments, that the complete process of generation requires the access of the semen to the rudiments, it seems equally certain, from a variety of appearances which I noticed in the course of my experiments, that to a certain extent, though imperfectly, it may be accomplished without it. These appearances I shall now proceed to state.

In both the uterine and vaginal experiment, the womb, though it contained no fœtuses, in many cases enlarged, as in extra-uterine pregnancy. Its structure too became developed; it received more copious supplies of blood; in short, it frequently seemed as well prepared as its fellow, for receiving and cherishing the rudiments.†

The ovaries, too, I may further add, although there was no genuine impregnation of them, were very obviously excited. The vesicle in different parts of them germinated; its fluids increased; the delicate covering opened; the little cavity discharged its contents, and corpora lutea formed in all their perfection. As this appearance of the *corpus luteum*, notwithstanding the interception of the semen, is of considerable importance, and may help to clear away an objection to which the experiments lie open, it becomes necessary to examine it with attention.

The corpus luteum in the rabbit, as long as it remains, is, I think, *always* marked by pretty strong characteristics, though its appearance differs considerably with its age. A mammillary projection of the ovary, an augmented vascularity, a minute cavity, which, when the luteum is cut through, recalls to mind the appearance of a printed asterisk (*), constitute the leading characteristics; and by these, I may add, it is so decisively marked, that, although the parts are on a small scale, an experienced eye may detect it at a glance. Colour is of little use in distinguishing these bodies in the rabbit. The younger the *luteum* is, the more prominently the characteristics appear.‡

* In operating upon the viscera of small animals, I have occasionally used a very slender ligature, have cut it short, and left it. In two rabbits, which had apparently recovered after the vagina had been tied in this manner, a general inflammation of the belly came on about six months afterwards, in the winter, when the health of the animals was impaired by the severity of the season. On inspection after death, it was found, that the ligature still adhered to the vagina, and it seemed to form the centre from which the inflammation had spread.

† It deserves notice, that, in the uterine experiments, it was generally the Fallopian portion of the womb to which the semen was not applied, and not the vaginal to which it was applied, which appeared to undergo these changes in the highest degree.

‡ In giving the name of *corpus luteum* to the appearance here described, I merely adopt the nomenclature of preceding physiologists; and in stating my belief that this appearance is the result of impregnation, or, at most, of the sexual excitement when exalted to its highest pitch, I am only advancing an opinion, which is, I conceive, *as far as respects the rabbit*, confirmed by observation. I have frequently examined the ovaries of the doe, in the virgin condition, and during heat; and in one or two cases, after the animal had been under the influence of long-continued and lively desire. In the two last instances I have never found the appearances described, though

Now, these lutea, thus characterized, were distinctly produced both in the uterine and vaginal experiments. In the uterine experiments I had an opportunity of contrasting those of the fruitful and sterile ovary with each other, and yet, after the most deliberate examination, I could not discriminate the slightest difference between them. It deserves notice, also, that in some instances they were more numerous upon the prolific, and in others upon the barren side of the genitals.

In these experiments, it may be further remarked, the Fallopian tubes, as well as the ovaries and wombs, seemed to be excited by coition. I observed repeatedly, in those experiments in which the vagina was interrupted, that the abdomen of the doe enlarged in a few days after the sexual commerce; and that enlargement, never noticed before, and gradually decreasing* in a few weeks afterwards, if the male was excluded, might by repeated coitions be carried to a very great degree. There is now in my possession, a doe with an interrupted vagina, which has admitted the male from twenty to thirty times. In this animal, in consequence of these repeated connections, the abdomen has gradually acquired so large a size, that it considerably exceeds the bulk of mature gestation, and reminds one of the tumour of an ascitic which requires the trocar. These enlargements, I have ascertained from repeated dissections, result from the accumulation of a humour in the wombs. This humour, various in its consistency and colour, is, however, generally fluid and pale, and turbid, and always, so far as my experiments have extended, forms albuminous concretions at a temperature below boiling heat. Even in the uterine experiments, (for the preceding remarks refer to the vaginal only), the same essential appearances were observed; the wombs, in consequence of impregnation, became filled, on the sound side, with fœtuses, and on the barren with the humour described.

These facts are very significant. The formation of the lutea, the development of the wombs, and above all, the repeated accumulations of fluid there, in consequence of coition, all seem to indicate the descent of the rudimental material; and reflecting upon them, I cannot forbear imagining that the tubes were excited, that they really transferred the rudiments to the womb, and that these rudiments engendered the watery accumulations there, in the abortive attempts of generation. This notion receives some little countenance from the generation of oviparous animals; for in many of the different species referred by naturalists to this class, the rudiments may be discharged independently of preceding impregnation. The common fowl is an example of this; the frog, the toad, and a numerous tribe of fishes. This opinion, however, is merely conjectural, and I must acknowledge candidly that it is the less entitled to confidence, as it rests on a sort of accidental observation, made subordinately, perhaps with some degree of remissness, at a time when others of greater importance in the inquiry occupied a principal share of my attention. This remark I take the liberty of introducing here, as I conceive it to be the duty of every experimental inquirer *himself* to distinguish between his conjectures and demonstrations, and thus, by the exercise of a philosophical frankness, to prevent error from insinuating itself from its association with truth.

On the whole, then, it seems probable, judging from the appearances related, that generation may be carried forward to a certain extent, although the access of the semen to the rudiments is intercepted. Under these circumstances, the young animal cannot be formed, it is true; but corpora lutea may be generated;

I dare not, from a negative observation of this kind, deny, that, under these circumstances, their formation is possible. In the first case, on the contrary, I have invariably discovered them, and older or younger in their appearance, according as they were examined sooner or later after impregnation. There can, therefore, I apprehend, be little doubt, that these appearances occurring *in the rabbit*, are the result of conception. This fact is sufficient for my reasoning. It may, indeed, seem irreconcileable with the opinion which a veteran physiologist has formed, respecting the nature of the human corpus luteum (see Philosophical Transactions); but so long as it appears to be confirmed by observations, conformably to sound philosophy, it cannot be denied. I am far, however, from wishing rashly to impugn the opinion of Sir Everard Home. Truths once proved must be admitted, and their apparent inconsistency demonstrates our ignorance, not their incompatibility.

* It did not however subside completely.

the wombs may be developed; and the rudiments, if we may judge from the facts already stated, may even be transferred to the uterine cavity by the play of the Fallopian tubes.

It should be remarked, however, in dismissing this part of our subject, that these imperfect attempts at generation do not always equally occur. Corpora lutea, I believe, will be found to form invariably after sexual intercourse, if the genitals are excited at all; but in some anomalous instances, there is no consequent development of the wombs, and in others, no accumulation of the uterine fluid. The first of these failures has occurred to me once in twelve experiments, and the last of them five times.* But these *negative* irregularities merely prove, that, under circumstances, the genitals may be more extensively excited at one time than another. They by no means invalidate the principle which it has been my endeavour to establish on positive facts, that the ovaries, tubes, and *uterus*, are capable of an imperfect excitement, even when the semen and the rudiments are kept apart from each other.

Against the experiments and reasonings advanced in the preceding pages, various objections may be urged, to which it may now be proper to advert.

And first, it may be objected that sterility is sometimes an accidental occurrence. We frequently observe it in human generation. In the experiments under consideration it would perhaps have occurred, although the interception of the semen, to which it is ascribed, had not taken place. To these objections, however, I would reply, that in the rabbit the accidental failure of impregnation is rare, and does not occur in one doe out of twenty, if the animal is in health; that the appearance of the genitals, and the behaviour of the female when the male was admitted, both of them indicated inclination and aptitude for generation; that these experiments were not solitary, but frequently repeated; and that sterility was not an accidental occurrence, in a single instance only, but an invariable result of them all. Nor must it be forgotten that the formation of the *lutea*, and the evolution of the *uterus*, are themselves sufficient proofs that the genitals were not accidentally inactive; nor that in the uterine experiment, in which the semen was intercepted on one side only, there were undeniable proofs of the generative excitement in the formation of the young animals on the other.

But there is another objection to which the experiments lie open, which, on a cursory consideration, at least, may appear to bear with considerable weight. In these operations either the wombs or the vagina were cut asunder. It may be asserted therefore that sterility ensued, not so much in consequence of the interception of the semen, as from the debility induced in the genitals by operative violence; the germs afterwards perishing because the soil was become unfriendly.

To this plausible objection, however, it might be sufficient to reply, that from the form of the parts the injury of the operation is merely local; that when the vagina is cut through, before puberty, the genitals suffer so little from it that they are afterwards brought to maturity in the same manner as if no operation had been performed; and that in both sets of experiments, whether uterine or vaginal, the wombs frequently become enlarged and developed, and like a fruitful and well dressed soil (to resume the figure already adopted), are brought into high condition for raising the rudiments to perfection. To obviate this objection, however, in a still more satisfactory manner, the following experiments were instituted.

I divided the vagina of two young does, just before their puberty; but instead of securing the uterine piece to the verge of the abdominal wound, I allowed it to remain in apposition with the other. In consequence of this method of operating, the parts reunited; the canal of the vagina was renewed; and the sexual desires appearing a few weeks after recovery, both the rabbits became impregnated. The inference is obvious.

The second set of experiments, turning on the same principle, was executed on the wombs themselves. In these, both the wombs were divided, the one in two, and the other in three places, in such a manner, however, that the incision

* In one or two instances the orifice formed by dividing the uterus remained open in the Fallopian piece. This accounts for some of the failures of uterine accumulation.

was not carried completely across into the mesometry; so that the pieces were retained in mutual apposition, and reunited without interruption to the uterine canal.

The result of these experiments was decisive. From the very method of operating, it is obvious the wombs were more roughly handled in this than in any of the preceding experiments; accordingly a larger number of the rabbits died; and yet, notwithstanding this violence, the very first doe which recovered produced no less than nine fœtuses from her *first* intercourse with the male. Indeed so complete was the action of the *uterus*, that there was not one of the little masses of rudimental matter which it failed to mature; and it was found, on a careful comparison of the wombs with the ovaries, that the number of fœtuses and corpora lutea was the same. To these remarks I may add, that the human womb, although it has been cut or torn, or partially destroyed by ulceration, still retains the power of maturing the rudiments. Healthy children have been born, not only after recoveries from uterine rupture and the Cesarian operation, but even at the time when the neck of the womb had been ulcerated. A case of this kind has lately fallen under my own knowledge; and others are recorded by obstetric writers.

There yet remains a third objection, which, it is conceived, may be completely obviated, though at first view it wears a very formidable aspect. The vagina of the rabbit is very long and very large; its course is not direct; the organ of the male can neither fill it nor penetrate to the orifices of the wombs; how then can the semen be injected into the uterine cavity, even granting that it might meet the rudiments there?

This objection, felt in all its force by those who have examined the genitals merely in the preparation glass, falls at once when they are viewed in the rabbit while it is living; or, to avoid unnecessary severity, immediately after the dealer has killed it.

Both the vagina and the wombs perform a peristaltic action, the wombs somewhat obscurely, the vagina in a more lively manner, even than the intestines of the animal themselves. This canal indeed, during the heat, is never at rest; it shortens, it lengthens, it changes continually in its circular dimensions; and, when irritated especially, will sometimes contract to one-third of its quiescent diameter. Now this peristaltic action, resembling the intestinal, is itself sufficient to explain the transmission of the semen.* In addition to this action, however, the vagina performs another, easily comprehended on inspection, although, as frequently happens, the verbal description of it may perhaps appear a little obscure. The action to which I here allude, consists in the falling down, as it were, of that part of the vagina which lies in the vicinity of the wombs; so that it every now and then lays itself as flatly over their orifices as we should apply the hand over the mouth, in our endeavours to stop it. So close is this application, that I have sometimes fancied I could perceive externally something resembling a little dimple, occasioned by the sinking of the surface of the vagina into the orifice of the womb. How well adapted the whole of this curious movement is for the introduction of the semen at the opening, it is needless to explain. The mere performance of it furnishes no contemptible argument in proof of that approach of the semen to the rudiments for which I have been contending.

Before I close these observations (already perhaps too diffuse) I cannot forbear adverting to some other points of the genital physiology, which they may contribute to illustrate.

It has been asserted by some naturalists, that the corpus luteum is an evidence of genuine impregnation. It seems *certain*, however, from the facts related, that this evidence cannot be relied on; for the luteum, in these experiments, was generated under circumstances in which, as the event proved, impregnation was impossible. Indeed there seems to be little reason for doubting, that the corpus luteum may be produced, even independently of the sexual intercourse, by the

* There is some little reason for surmising that even the human vagina can perform a sort of peristaltic movement. Two facts have been related to me which lead to this opinion, but they are of a character too delicate for public exposure.

mere excitement of desire in a very high degree. M. Saumarez has recounted experiments, in his "New System of Physiology," in which the *luteum* appears to have been generated in this very manner. I have now in my possession a preparation, (for which I stand indebted to Dr. Cholmeley and Mr. Callaway) consisting of the ovaries of a young girl, that died of chorea, under seventeen years of age, with the hymen, which nearly closed the entrance of the vagina, unbroken. In these ovaries, the corpora lutea are no fewer than four. Two of them, it must be acknowledged, are a little obscure; though an experienced eye, I conceive, would readily detect them. The remaining two are very distinct, and differ from the corpus luteum of genuine impregnation, merely from their more diminutive size, and the less extensive vascularity of the contiguous parts of the ovary. In every other respect, in colour and form, and the cavity which they contain, their appearance is perfectly natural, indeed so much so, that I occasionally circulate them in the class-room, as accurate specimens of the luteum upon the small scale.

On this point I have been the more explicit, both as the principle is of some importance in forensic medicine, and as it removes at once an objection to which these experiments lie exposed, and which is taken from those of Dr. Haighton. In these experiments, very ingenious, and extremely beautiful, my valued relative has shown, with his usual accuracy, that the corpus luteum may form, though the Fallopian tube has been obliterated in some part of its course, and the access of the semen to the rudiments therefore has been intercepted. When, however, he infers from this, in opposition to the principle asserted in this memoir, that the ovary has been impregnated, notwithstanding the interception of the semen, he certainly falls into one of those errors, from which the most wary physiologist is never absolutely exempt, for the corpus luteum is not a certain evidence of impregnation.

The appearances related, I may further remark, afford, when combined with others, a plausible proof that the semen sometimes penetrates as far as the ovaries; a point which has been much controverted.

In the varieties of human generation, we sometimes meet with extra-uterine pregnancies, in which the ovum not only lodges in the tubes, or the peritoneal cavity, but in the ovary itself. Indeed, this form of the disease seems on the whole the most common. Now, if it be true, as I have endeavoured to prove, that the young animal cannot be formed unless the semen have access to the rudiments, it is evident, that in these pregnancies, in which the fœtus is generated among the Graafian vesicles, the semen must have made its way up to the ovaries themselves. It must not, however, be too hastily inferred from this, that the semen always penetrates into these remote recesses of the genitals. Facts have been related, which give a shade of probability to the conjecture, that without the contact of the semen the rudiments may sometimes descend into the uterus; and certainly, although the opinion is not without its difficulties, it is not impossible that they may meet each other there.*

There is yet a third point in the physiology of generation, which the preceding experiments may contribute to elucidate. It has been contended by some naturalists, and not without show of reason, that the semen in generation is transferred to the blood-vessels; and as the purgative or emetic, when injected into the veins, exert their peculiar influences on the stomach or the bowels, so also, in their opinion, this active fluid, transmitted by the absorbents, makes its first impression on the vascular surface, and its second, by a similar sympathy, on the genitals themselves. What effects might be produced by injecting the semen directly into the veins when the genitals are in a state of excitement, I shall not venture to determine; as yet I am in possession of no decisive experiments upon the point, and it would be a mere waste of mind to speculate without them. It seems evident, however, from the facts related, that after transmission through the absorbents and their glands, the semen retains no such generative influence. It will be readily conceded, that when a rabbit admits a large male, in vigorous health, and

* Is the transfer of the semen beyond the womb the cause of extra-uterine pregnancy?

in the flower of its age, as many as twenty or thirty times, a large quantity of the genital fluid must be imbibed by the absorbents of the vagina, yet neither in the uterine nor the vaginal experiment, in which these repeated coitions sometimes took place, was impregnation by absorption accomplished. The simple exclusion of the semen from the rudiments always prevented the formation of the young animal; in the vaginal experiments it was not produced at all; in the uterine it was formed on that side only where the womb remained pervious.

On a review of the whole inquiry, it will, I conceive, appear not improbable that, for the completion of generation, the semen must have access to the rudiments; and yet that notwithstanding the necessity of these approaches, for its completion, the process to a certain extent may be accomplished without them. These are the two leading propositions which it has been my endeavour to establish; at the same time I have subordinately attempted further to show, that the corpus luteum is not a proof of genuine impregnation; that the semen, at least occasionally, penetrates as far as the ovaries; and that however copiously this fluid may be absorbed into the vessels, it is incapable of giving rise, by any impression there, to the complete circle of the generative actions.

Whether these principles of brute generation may be transferred to our own, I will not venture to determine. Analogical arguments, generally the best that physiology furnishes, are, it must be admitted, never absolutely demonstrative; but as the generation of the rabbit, in its other principles, resembles that of the human female, there seems to me but little reason for supposing that there is an essential difference here.—*Medico-Chirurgical Transactions, Vol. X.*

On the causes of the Vacuity of the Arteries after death. By JAMES CARSON, M. D. *Liverpool.*

THE Harveian doctrine of the circulation of the blood, may, I think, be divided into two parts. The first is the course of the blood; the second the explanation of the causes by which it is moved in that course. The arguments advanced by Dr. Harvey on the first of these points, the course of the blood, must, I think, convince every candid inquirer that the blood is conveyed from the heart by the arteries, and returned to it again by the veins. But the illustrious discoverer has not been so fortunate in the second part of his great undertaking. In maintaining that the projectile power of the ventricles of the heart propels the blood through the whole of the arterial and venous canals, and, after having discharged this office, opens the auricular chambers by means of the returned blood, he lays claim to effects which are not warranted from the supposed causes, and which are inconsistent with the established laws of hydrostatics; laws by which the blood, as well as every other fluid, must be governed. But this part of the doctine of Harvey, admitting it to be philosophically correct, must be rejected in its present application as affording no satisfactory solution of the phenomena. The followers of Harvey, adopting as the foundation of their argument his doctrine of a *vis a tergo*, have enlisted the arteries into the aid of the heart, and contend that the blood is circulated by the combined agency of these powers; but the difficulty is not removed by the supposition; it is only shifted to another part of the system, and the phenomena are not better explained.

It has often created surprise that a doctrine so simple in appearance as the circulation of the blood, and pointed out so plainly as we now suppose by facts of daily occurrence, should have been reserved for the discovery of modern times. The knowledge of the circulation seems to have been retarded by one remarkable phenomenon. The arteries, which are now known to constitute the channel of the blood for one-half of its course, were uniformly found to be devoid of that fluid after death. That vessels in which no blood was to be found by the most careful examination after death, should be the constant receptacles of it during life, is a supposition that would scarcely suggest itself to the anatomist; and, if suggested, would soon be rejected from the list of probable conjectures. The arteries were supposed to be the recipients of a vital aerial fluid. One fact indeed of frequent occurrence seemed to be at variance with this belief; and, if the effect of it had not been defeated by an hypothesis, it must, we would suppose, have led to the truth. An artery, when wounded, was constantly observed to discharge blood from the living frame. But the ancient physiologists, unwilling perhaps to degrade the arteries from what they conceived to be their more refined office, and conceiving it impossible, that if these vessels contained blood during life, they could be deprived of it by death, contended that the discharge of blood from a wounded artery was no proof that the vessel contained any blood before it was wounded, but that the injury and pain given by the wound drew blood from other quarters into vessels which contained none before; and that the impetuosity and obstinacy of the discharge arose from the conflict between this foreign intruder and the native aerial spirit. What gave greater plausibility to this supposition was, that the blood shed by the arteries, being of a different colour from that discharged from the veins, seemed to be not the natural product of the body, but the factitious result of this imagined conflict.

The condition of the arteries after death was urged confidently by the opponents of Harvey as an insuperable objection to the doctrine of the circulation, upon its first promulgation; and was unquestionably one of the greatest obstacles found in the path of the discoverer; and, after all, the explanation given by this celebrated man of the powers by the operation of which the arteries are found empty after death, is most unsatisfactory. He says that the left ventricle, in the last struggles of life, continues to propel after it has ceased to receive blood, and that, by these final propulsions, the blood at the time in the arteries is driven into the veins; and he further asserts, in support of this explanation, that the arteries of animals, who have been killed by submersion in cold water or by mephitic air, will be found to contain blood after death as well as the veins. But there can be nothing more evident, than that the heart by these abortive impulses, could only drive blood through the more remote portions of the arterial system by some impinged medium; and that this medium, which, upon the hypothesis of Dr. Harvey, could only be blood, must still remain in the arteries. But defective as this explanation is, it has the further imperfection of being built upon an hypothesis that is altogether destitute of proof. This hypothesis is, that the heart continues to propel after it has ceased to receive blood. The heart on the contrary is generally found full of blood after death. The converse, therefore, of what is maintained by Dr. Harvey would appear to be the truth, that the heart retained the capacity of receiving blood, after it had lost the power of discharging it. The statement also by which Dr. Harvey has supported his opinion, has not been confirmed by observation. The arteries of animals which have been killed suddenly by submersion in cold water, or by any of the ways enumerated by Dr. Harvey, have been found equally empty of blood with those of animals killed by lingering disease. Into such a labyrinth of error and evasion will men of the most powerful minds be led when they attempt to shape nature to a conformity with their opinions.

No new light has been thrown upon this subject by the followers of Harvey; and in general it may be observed that after the lapse of two centuries, and though a thousand volumes have been written, and thousands of animals slaughtered to elucidate the subject, the doctrine of the circulation has descended to our times nearly in the same state in which it came from the hands of the original discoverer.

Mr. George Ker, an ingenious and learned surgeon in Aberdeen, struck with the defectiveness and inapplicability of the explanation given by Dr. Harvey and his followers of this remarkable phenomenon, as well as of many others, has in a late publication boldly denied the doctrine of the circulation of the blood altogether, and become the acute, strenuous, and most confident advocate of the opinions of the ancient physiologists respecting the condition of the blood in the living system, and the uses of the arteries.

All the objections urged by Mr. Ker against the circulation had been stated by myself as objections, not against the doctrine of the circulation itself, which I believe to be founded on a basis never to be shaken, but against the causes assigned for the accomplishment of that effect, at least two years before the appearance of Mr. Ker's work, but unquestionably without the knowledge of that gentleman. The causes which I have ventured to assign to the motion of the blood, will, in process of time, I trust, be found to have a real existence in nature, to be adequate to the effects assigned to them, to have been fitly applied, to afford a plain and satisfactory explication of the various phenomena, to answer fully all Mr. Ker's objections, and, in a word, to vindicate a theory, which does so much honour to our country, from all future opposition.

The objection principally dwelt upon by Mr. Ker, the emptiness of the arteries after death, did not pass unnoticed, as may be seen on reference to the inquiry into the causes of the motion of the blood; but as I had not then had an opportunity of submitting my opinions to the test of experiment, I did not state them with that confidence which I even then felt in their truth. I have lately had that opportunity, and I now propose to state the result.

The chief, if not the whole, of the movements of the animal machine seem to be the effect of two powers acting either conjunctly or separately. These are elasticity and irritability. The elasticity of the parts which possess this property is inherent in the structure, and is independent of life. Irritability, which is the property of the muscular substance, is the concomitant of life, and ceases with it. The movements, which are the usual result of a combination of those powers, will not wholly cease at death. The elasticity will still continue to operate; and the result will be different, either from that which would be produced by their combined agency, or from that which would arise from their synchonous destruction.

The motion of the blood seems to be the result of the contractions arising from the irritability of the heart and arteries, and of the resilience arising from the elasticity of the arteries and of the lungs. One class only of these powers is destroyed by death. The resilience of the lungs and of the coats of the arteries possess then an uncontrouled operation.

The resilience of the lungs removes a part of the pressure of the atmosphere from the internal surface of the chest, and perhaps from the internal surface of the vessels by which they are penetrated. To restore to the parts within the chest an equality of pressure with that of the substances without it, the adjoining liquid and less fixed parts of the body will be pressed through every channel that offers into the chest. What is called a vacuum will in effect be made in the chest by the elasticity of the lungs. There will therefore be a draining from all parts of the body towards the chest, to fill up this vacuum. As thus the causes which return the blood to the heart continue to operate, after the heart, the great engine by which it is discharged, has terminated its labours, a greater quantity of blood will be necessarily collected in the neighbourhood of the heart after death, than existed there before it.

Various circumstances may intervene to fix the channels in which the blood will flow in its course towards the heart after death. The arteries are powerfully elastic, and when their coats are relieved from the distending force of the heart, become of a diminished calibre. Valves stationed at the roots of the arteries prevent the return of blood from these vessels into the chest. After the small part of the aortic system intervening between the heart and the confines of the chest shall have been, as it usually is found to be, filled with blood, the blood in the rest of this system will sustain no diminution of pressure on the side of the heart.

No obstacle exists in the way of the blood in its course to the chest through the veins. No valves are stationed at the roots of these vessels, and the blood finds an unobstructed course from the roots of the cava into the auricles, from that possibly into the right ventricle and into the pulmonary arteries, and thence into the pulmonary veins. The heart, particularly the auricles and the large venous trunks, the coats of which being inelastic and easily dilatable, being all placed within what may be called the vacuum of the chest, will be distended to their utmost capacity. The additional blood requisite for this purpose can be drawn only from the veins. The place of the blood taken from one part of the venous system will be supplied by that from another. The termination of this process will be the emptying of the arteries into the veins.

If the preceding argument be correct and founded upon true principles, it would follow that, were the elastic powers employed in the motion of the blood disengaged before the muscular powers had ceased to act, or synchronously with that event, a distribution of the blood would be found to exist after death different from that which is now usually observed. The blood would not be found so extraordinarily accumulated in the right auricle, and in all the veins belonging to the system of the cava within the chest, and at the approaches to it; and the arteries and capillary vessels would contain the proportion which upon the supposition of the Harveian theory must have flowed in them before death. I have not been able to devise any method of annihilating before death the elastic influence of the arteries, and therefore some allowance must be made in the phenomena which are to be brought into view for that cause; but I have been successful in removing from all influence after death the elastic power of the lungs, by far the most efficient, by the manner in which the animals were killed in the following experiments. Death was in these cases effected by inducing a previous collapse of the lungs, which was done by making openings into the chest of the living animal, and exposing the external surface of the lungs to the free access of the air.

In the first experiment made with this intention, an opening was made about an inch in length between a pair of the ribs on each side. I expected that sudden death would be the effect of these openings; but in this respect I was disappointed, and at first not a little perplexed. This disappointment I experienced particularly in the case of a large dog. This animal, as I supposed, after the collapse of the lungs, by pressing up the diaphragm by means of the abdominal muscles as far as possible, and then by a rapid and forcible contraction of the intercostal muscles, accompanied by a rapid and forcible contraction of the diaphragm, was enabled to rarefy the air contained between the external surface of the lungs and the chest to such a degree as to occasion a partial dilatation of the lungs, and an imperfect expansion of the heart. Thus life was painfully prolonged for nearly twenty minutes. The sufferings sustained by this animal for so long a period prevented a repetition of the experiment on any other animal in the same manner. The result was in other respects satisfactory. Though the death was tedious, it was ultimately produced by the collapse of the lungs. I had previously performed the same experiment upon a rabbit and a cat. In these the death, though not sudden, was neither so tedious, nor to appearance so distressing as in the case of the dog.

The same appearances were, on dissection, exhibited by all. The muscles were remarkably red; and when an incision was made into them, they poured out blood. The membranous parts exhibited the blood-vessels as if they had been fully and nicely injected; forming anastomoses which appeared like a netting made of red threads. I was particularly struck with the coats of the intestines; instead of exhibiting the usual pale smooth surface without the vestige almost of a single blood-vessel, they appeared to be composed of a red coloured netting, the meshes of which varied greatly both in dimension and in form. The liver was like red morocco. The flesh of the rabbit, which is usually white, was in this case of a reddish colour, and all the dissected parts became wet with effused blood. The heart contained little blood. When the chest was opened, and the large vessels it contains were divided, a small quantity of blood only was effused, not much more indeed than from the other parts of the body. The aorta and large arteries, in all the instances, were pale externally, while the accompanying veins were of a blue colour. A part of the descending aorta, above the bifurcation of the iliacs, after its extremities had been secured by ligatures, was cut out, and was found to contain a small cylinder of blood generally coagulated. So it appears that the white colour of the arteries did not arise from their being empty of blood, but from the want of transparency of their coats. With respect to the vessels, which the stomach, the intestines, and the membranous parts exhibited in so beautiful a manner, I do not pretend to say what part of them may have been arteries. Supposing, however, that these carcases exhibited the distribution of the blood as it really existed in life, it is very evident that the blood, not only of the larger arteries, but of the smaller vessels, whether they be arteries or veins, must, in consequence of death produced in the usual way, be emptied into the large veins. I think it probable, however, that what are called the capillary vessels, may, in consequence of this mode of killing the animal, be found to contain more blood than the share that belonged to them during life; for the elasticity of the coats of the arteries, the effect of which, as I before stated, I had not been able to devise any plan of counteracting, by contracting the bore of these vessels, would propel a part of the blood that was flowing in them at the moment of death into the vessels, the coats of which were inelastic and dilatable.

For the pursose of comparing the appearances of two animals of the same kind, killed in different ways, two rabbits were killed on the 20th of September 1819, one of them by causing the lungs to collapse before death, the other after a different manner. In the case of the first of these rabbits, the belly was opened freely from the scrobiculus cordis nearly to the pelvis, and the lower surface of the diaphragm exposed to view. An opening, fit to admit my two fingers, was made through the muscular part of the diaphragm on each side. The sound of air rushing through the orifices, announced the collapse of the lungs. As the animal possessed no power of contracting the openings made in the diaphragm; as its struggles would probably tend to widen them still more; and as therefore the capacity of dilating the lungs, even in the smallest degree, no longer remained, the animal instantly died. The appearances exhibited by the dissection of this rabbit, were precisely similar to those already described of the bodies of animals killed by the previous collapse of the lungs. The vessels, particularly of the intestines, stomach and mesentery, were very distinct and full of blood, forming frequent anastomoses with each other, in the way already described. The flesh was reddish, and when cut into, bled. The heart and vessels about it contained only a moderate quantity of blood; for scarcely any blood was found, after the division of the vessels, to have been effused into the shell of the chest. The other rabbit was killed by thrusting a sharp instrument between the vertebræ of the neck. It died instantly, and was immediately opened. Scarcely was the vestige of a blood-vessel to be observed on the surface of the intestines or stomach, which had a pale appearance, excepting where they were tinged by the colour of their contents. The membranes scarcely exhibited any traces of vascularity. The flesh was white, and when cut into, appeared to be dry, discharging at some parts a drop or two of blood. The liver was of a dusky brown colour. The trunks of the veins were swollen and rounded; whereas in the other rabbit they appeared flat, and to contain a thin layer of blood. A considerable quantity of blood was found in the shell of the chest, after it had been opened, and the large vessels it contains divided.

A few days after, a sheep was killed in the same manner as the first of the above-mentioned rabbits. When the openings were made through the diaphragm, the sound of air rushing into the chest, announced still more plainly the fatal collapse of the lungs, and the last expiration. The animal, after making a few heavings with the chest, became lifeless. Several other sheep had been killed at the same place at that time, and there was an opportunity of comparing the carcase of this animal with those of the others. Scarcely any traces of the smaller vessels were observable in the stomach, intestines, peritoneum or mesentery of the other sheep, while in the same parts of this animal they appeared in great abundance, and as injected with red wax. The appearance was so remarkable as to strike the butchers, and the persons whose attention I directed to it, with surprise. The colour of the fat was browner than usual. The muscles of this animal being at all times red, did not exhibit so marked a difference as in the case of the rabbits, but when cut into they discharged blood. The larger arteries, where I had an opportunity of seeing them, contained a small cylinder of coagulated blood. The flat and tape-like appearance of the large veins, which I had observed in the rabbit killed in the same manner, was in this case very remarkable.

The results of these experiments I think fully warrant the conclusion, that the difference of the distribution of the blood after death from that in which, according to the Harveian theory, it must exist in the living system, arises chiefly from the elastic power of the lungs; and that the emptiness of the arteries and of the smaller vessels observed after death, admits of a satisfactory explanation from the supposed operation of this cause, combined with that of the elasticity of the arterial canals.

Before I conclude this paper, I am anxious to express my hope that some benefit may result to anatomy from the examination of animals killed by the collapse of the lungs; in particular a better chance seems to be promised by it of tracing the vascular system to its various terminations. According to the Harveian doctrine, the blood must flow from the minute and ultimate branches of the arteries into the corresponding branches of the veins. But the knowledge of the manner in which the vessels form the communication necessary for this purpose, is still a desideratum in medical science; and, as in all the ordinary modes of death, these vessels are always deprived of their contents; and, as in these circumstances, the knife of the anatomist and the microscope, though directed by all the colourings which the art of injecting can supply, have been found incapable of bringing this union into view, it was likely to have remained so. But the examination of animals in which the smallest vessels contain at least their full proportion of the red fluid that filled them before death, seems to hold forth the hope of some more satisfactory knowledge being attainable in this dark and mysterious part of physiology.—*Medico-Chirurgical Transactions. Vol. XI.*

Mr. Brodie's *Experiments on the Effects of the Bile in Digestion.*

It appears that Mr. Brodie, whose former physiological researches are of the highest merit, has been for some time employed in experimenting on digestion; and as a specimen of what is to follow, he has published some experiments made chiefly on young cats, respecting the effects of the bile. He was disposed to think, that the bile is intended to convert the chyme into chyle by a chemical change; but to ascertain whether he was right in this, he completely obstructed the flow of the bile into the duodenum, by a ligature on the ductus choledochus. It is properly premised, that neither this, nor the ligature on the whole extremity of the pancreas, and the division of the ramulæ of the eighth pair on the cardia of the stomach, produce much suffering or derangement, for digestion goes on, and chyme is formed, as if nothing had happened. The ligature and the consequent want of bile, completely and invariably prevented the changing of a single particle of chyme into chyle—a process which takes place at the entrance of the duodenum, and never higher than the pylorus, above which Dr. Prout could never find any albumen—the chief constituent of chyle. No chyle could be traced in the intestines, or in the lacteals; but both of these were filled with a fluid like the chyme, which became thicker as it proceeded, and at the termination of the ilium, it was quite solid, though not like fæces.

The office then of the bile is to convert chyme into chyle. In cases where there has been morbid obstruction of the choledoch duct, Mr. Brodie thinks it has either not been complete, or when obliterated, has been attended with extreme emaciation: or that nutrition has been imperfectly maintained by the chyme, as appeared from the preceding experiments.

A singular and interesting fact was discovered while prosecuting these experiments. When the animal was allowed to live, it became jaundiced, and bile was seen in the eyes, and in the urine. At the end of seven or eight days, nature had made an effort to repair the injury, by a mass of albumen, (coagulable lymph) being effused above, below, and around the ligature; which, in consequence of ulceration, lay loose in the cavity thus formed. A new passage was in this manner formed for the bile. The same phenomena occurred when two ligatures were used. Mr. Travers observed a similar phenomenon, when a ligature was applied round an intestine.—We anxiously wait for the rest of Mr. Brodie's experiments.—(Brande's *Journal.*)

M. Magendie *on the Functions of the Spinal Marrow.*

In following up the novel experiments of Mr. C. Bell, M. Magendie remarks that, in general, the properties of the spinal marrow appear to reside at the surface of the part; this is at least evident as regards sensibility. If the posterior cords, covered even by their vascular membranes, be touched, we observe signs of an acute pain, and, what is worthy of remark, very marked contractions in the muscles which receive their nerves, lower down than the part touched. The contractions only show themselves on the side of the cord which is irritated.

It would be, doubtless, very desirable to know how sensation and motion are propagated from the marrow to the brain. The anatomical disposition indicates that sensation should be directed more particularly towards the cerebellum, and motion towards the brain; but anatomy is not sufficient: it is necessary for physiological and pathological facts to confirm the indication: until the present time, however, neither the one nor the other of these means has established what anatomy seems to show in so evident a manner. Lesions of the cerebellum do not cause a loss of sensation. Removal of the hemispheres does not necessarily induce a loss of movement; the contrary assertion, announced by M. Rolando, is not exact: this physician appears to me to have suffered himself to be deceived by an accidental circumstance. When we wholly remove the hemispheres, an effusion of blood immediately takes place, and a coagulum is formed which fills the cavity of the cranium, compresses the medulla oblongata, and produces the state of somnolency (*assoupissement*) observed by M. Rolando. But if we prevent the formation of this coagulum, the symptoms are quite different; the animals are in continual agitation; they run or fly with remarkable agility, provided they are not too much weakened by the loss of blood. The animals on which this experiment succeeds the best, are small rabbits, a month or six weeks old, and young jackdaws, or magpies, just beginning to feed alone. It is singular to see them run, leap, &c, of their own accord, after the complete ablation of every part of the brain, situated a little before the optic tubercles. But if the section be made immediately before these last eminences, every thing is arrested; the animal falls upon the side, the head is thrown backwards, the paws entirely stiff and directed forwards. I have seen young rabbits remain several hours in this position. In order to put an end to it, it is sufficient to make a section behind the optic tubercles. Immediately the anterior paws lose their stiffness, and most commonly, become bent as well as the posterior, and the head is again brought forwards. It seems to me, to be evident from these facts, that the optic thalami, the crura cerebri, and the tubercula quadrigemina have functions relative to motion, and these parts should be examined under this new point of view.

The effects of a partial or total removal of the cerebellum are much more difficult to observe, by reason of the great hemorrhage which always accompanies a wound of that organ, of the effusion which is the inevitable result of it, and of the compression of the spinal marrow. I have not yet been able to assign to each of these effects, the part it takes in the phenomena which occur at the time of wounds or ablation of the cerebellum: it is easy, however, to prove, that profound lesions of the cerebellum: and total ablation of it, do not cause the loss of sensation. The experiments of Larry, Legallois, &c., have, besides, demonstrated that this quality is inherent in the spinal marrow. It is to be hoped, that this difficulty will be soon removed, for several zealous individuals are occupying themselves with researches on this point, and I am myself using all my endeavours to arrive at something satisfactory on this important question.

What I have hitherto remarked most constantly is, that the cerebellum seems necessary for the integrity of the forward motion. Every triflingly severe wound of the cerebellum totally prevents progression, and most commonly develops, on the contrary, a set of movements which belong to the action of retrogression. A duck, from which I removed a great part of the cerebellum, could swim backwards, and made no progressive movement for eight days.—(*Journ. de Phisiol.*)

On some Changes produced by Reagents on Animal Matter, and on the Nature of the Blood.

At the sitting of the *Société de Pharmacie* of the 12th of April last, M. Magendie read a report on a work by M. Chevreul embracing the above topics.

The author had proposed to himself for inquiry, whether azoted organic substances became converted into fatty matters by putrefaction, nitric acid, &c.; or, as Berthollet had advanced in 1780, whether the fatty matter extracted by these means pre-exist in the substances employed.

When the dried tendons of the elephant are treated with alcohol, a fatty substance is obtained, fusible at 30.5 (R.?), the composition of which is similar to that of the fat of the same animal.

If the tendons be treated by nitric or hydrochloric acid, an equal quantity of the same fat is extracted.

These three reagents, so different amongst themselves, alcohol, nitric, and hydrochloric acid, give the same results as regards the fatty matter obtained.

The same tendons, left for a year in water, scarcely yield 0.02 or 0.03 of a substance formed of the margaric and oleic acids—a substance which, in its nature and quantity, corresponds with the proportion of fat which may be extracted by means of alcohol.

On treating the same tendons with a solution of potass, the organic matter is dissolved, and the liquid, left to itself, suffers supermargarate of potass to be deposited.

The yellow elastic tissue of animals, in which the proportion of fatty matter is greater than in the tendons, presents the same phenomena.

The fibrine of arterial blood, treated with alcohol and ether, yields a fatty matter, the proportion of which it is difficult to estimate, from its forming with water a sort of an emulsion: this circumstance does not occur with fat formed of principles immiscible with water.

The fatty matter extracted from fibrine differs considerably from other fatty matters: on a comparison of all its physical and chemical properties, it may be considered as identical with the fatty matter of the brain and nerves.

From these different experiments, M. Chevreul concludes:—That the fatty matters extracted by means of alcohol and the nitric and hydrochloric acids are not, as advanced by M. Berzelius, a product of the reaction of these agents; but that they are constituent principles of azoted organic matters.

In the second part of the *Mémoire*, after some general reflections on the comparative nature of the blood in a state of health and disease, an important fact is adduced relative to the disease of new-born children known under the name of induration of the cellular tissue—a disease almost always mortal.

If the skin of individuals dead of this disease be cut into, a yellow liquid runs out, composed of albumen, of an orange-red and of a green colouring principle. These colouring matters are found in the bile of the same children. The blood of jaundiced children yields coagula formed of albumen and fibrine, as in health;

but the serum differs considerably from that of health: its composition and colour are the same as those of the liquid obtained by incising the skin. A property common to both fluids appears to be the cause of the disease: these liquids, when left to themselves, assume the form of a jelly composed in part of a membranous matter: the colouring principles remain in the liquid portion.

The reporter properly considers, that, in order to render these results still more positive, it is desirable that M. Chevreul should subject the blood of a child in a state of health to a comparative examination.—*Journal de Pharmacie, Juin*, 1824.

Effect of Castration in certain Animals.

M. Faneau Delacour, of Souzay, has performed a number of experiments upon sheep and pullets, with a view of determining the effect of castration upon the animal economy, conceiving that the loss of organs so important as the testicles, could not take place without materially affecting the health; which opinion was strengthened by considering the sudden evils often arising from more trifling causes,—such as the disappearance of eruptions, or the drying up of a long-established ulcer.

M. Delacour had eighty pullets castrated in his presence: eleven of these immediately exhibited well-marked signs of cerebral affection, and in three others the symptoms were observable, but not to so great a degree. Of eight which became mad, four of the worst, as well as two out of three which were threatened with apoplexy, were cupped upon the rump, and an actual cautery applied on each side of the cupping-glass; and in the four first instances, a cautery was also applied on the head. All these recovered: whereas, one left entirely to the efforts of nature died on the third day, the brain exhibiting the strongest marks of inflammation.

The same phenomena were observable among a flock of sheep, and in a greater proportion. The same remedies were made use of in seven of these animals, and they all recovered on the day the cauteries were made: whereas, two left entirely to nature died,—one on the fourth day, with all the marks of madness; the other on the second day, in a state of coma. The examination of the heads showed, in the first instance, a violent state of inflammation of the brain and its membranes: the brain of the second was softened, and the ventricles filled with a fluid resembling the white of an egg a little coloured.—*Journal Universel des Sciences Medicales*, Juin.

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APPENDIX.

THE END.