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BICHAT

PHYSIOLOGICAL RESEARCHES

ON

LIFE AND DEATH,

BY XAVIER BICHAT;

Translated from the French,

BY F. GOLD,

MEMBER OF THE ROYAL COLLEGE OF SURGEONS, LONDON:

WITH NOTES,

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THE NOTES TRANSLATED

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TRANSLATOR'S PREFACE.

THE Translator of the Work which is here offered to the Public, feels it quite unnecessary to expatiate upon the merits of its Author, whose ideas and classifications in Physiology are now very generally adopted. He has supposed, however, that the experiments which constitute the *Second* Part of the Work, are not so familiar to Professional Men, as many of the conclusions which have been deduced from them, and therefore has presumed that a greater publicity of these experiments will by no means be unserviceable. Dr. Kentish, in his account of Baths, has mentioned the circumstances which led to this translation.

ADVERTISEMENT BY THE FRENCH EDITOR.

THE work of Bichat, which appears to the most advantage, is the one that we now reprint; his observing mind, his experimental genius and his lucid manner of exhibiting facts are particularly observable in it. This work will have for a very long time a great influence on physiologists and physicians.

The Physiological Researches on Life and Death have had more than one class of admirers. Exact minds, friends of the progress of science have praised it for the great number of accurate observations which it contains, the ingenious management of the experiments and the correctness of the deductions; but they have regretted that the author constantly placed life in opposition to physical laws, as if living beings were not bodies before they were vegetables or animals. They have seen with regret that he offered illusory explanations of inexplicable phenomena.

These grounds of legitimate criticism seem to have been the reason of the enthusiasm of another class of readers, for whom whatever is vague appears to have a great degree of attraction. The readers, of whom I have just spoken, feeling but little interest in the new facts which the Physiological Researches contain, have adopted without examination its fallacious hypotheses, and attaching to them an importance which the author never did, because they believed that they elucidated the mechanism of the most obscure vital operations, and conducted to a true theory of medicine. Should we lament this errour? Certainly not, as it has powerfully contributed to the brilliant success of Bichat's work, and by means of some errours, much truth has been promulgated.

As the works of Bichat have now become classics and their reputation cannot be increased, it is time to place young students on their guard against the errours into which the imagination of the author led him, and which are the more to be feared, as Bichat in order to convince, has employed all the fascinations of his animated style.

The memory of Bichat cannot but gain by it; the numerous truths which he has discovered will shine with a brighter light, when freed from the light shades that envelope them.

Such is the object of the notes to the present edition, which we have endeavoured to bring up to the present state of knowledge.

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PHYSIOLOGICAL RESEARCHES

ON

LIFE AND DEATH.

PART THE FIRST.

CHAPTER I.

GENERAL DIVISION OF LIFE.*

THE definition of life is usually sought for in abstract considerations; it will be found, if I mistake not, in the

* The form adopted by Bichat, in this work, has been much blamed by some, and extravagantly praised by others. The blame and the praise appear to me to be equally misplaced. His object was to exhibit the various phenomena of life; the order in which this was to be done was a matter of indifference. If Bichat gave a preference to this form, it was because it was conformable to the nature of his mind; and he accomplished his task in a very happy manner. The division that he has adopted is not new, it may be found, with slight modifications, in writers of different periods, and even in Aristotle. Besides, it is not necessary in the sciences to attach a very great importance to classification. All these contrivances have been invented only to aid the memory; and the functions of living bodies are not so numerous, as to render it necessary in studying them to lean upon systematic divisions.

following general expression :—Life consists in the sum of the functions, by which death is resisted.*

In living bodies, such in fact is the mode of existence, that whatever surrounds them, tends to their destruction. They are influenced incessantly by inorganic bodies; they exercise themselves, the one upon the other, as constant an action; under such circumstances they could not long subsist, were they not possessed in themselves of a permanent principle of reaction. This principle is that of life; unknown in its nature, it can be only appreciated by its

* The word *life* has been employed by physiologists in two different senses. With some, it means an imaginary being, the sole principle of all the functions which living bodies exhibit; with others, it means only the assemblage of these functions. It is in this last sense that Bichat employs it. This is what he means to say in the following sentence. *Life is the assemblage of the functions which resist death.* He is wrong only in allowing the idea of death to enter into it; for this idea necessarily supposes that of life. There is then really a bad circle in this definition; but in putting aside what is defective in the expression, it may be seen that Bichat considers life as a result, not as a cause.

Before and since the time of Bichat, a great number of definitions of life has been given, which are either false or incomplete. It should not be required of a definition, that it should give all the properties of the thing which it is designed to make known, this would be a description; but we have a right to expect that it should assign to this thing certain characters which belong to it alone, and thus distinguish it from every thing else.

Let us examine by this principle the definition adopted in a modern work. *Life*, it is said, *is the assemblage of the phenomena which succeed each other, for a limited time, in an organized being.* This is no doubt true of life; but, if it can also be applied to another state, it ceases to be a definition. An animal has just died; its organs from that moment are subject to the action of chemical affinities only; decomposition takes place, gases are disengaged, fluids flow out and new solid aggregates are formed. After a time every molecular motion ceases; there remains only a certain number of binary, ternary combinations, &c. Here then is an *assemblage of phenomena taking place for a limited time in an organized body*, and yet it is not life.

phenomena: an habitual alternation of action and reaction between exterior bodies, and the living body, an alternation, of which the proportions vary according to the age of the latter, is the most general of these phenomena.

There is a superabundance of life in the child: In the child, the reaction of the system is superior to the action, which is made upon it from without. In the adult, action and reaction are on a balance; the turgescence of life is gone. In the old man, the reaction of the inward principle is lessened, the action from without remaining unaltered; it is then that life languishes, and insensibly advances towards its natural term, which ensues when all proportion ceases.

The measure, then, of life in general, is the difference which exists between the effort of exterior power, and that of interior resistance. The excess of the former is an indication of its weakness; the predominance of the latter an index of its force.

I. *Division of Life into Animal and Organic Life.**

Such is life considered in the aggregate; examined more in detail it offers us two remarkable modifications, the one common to the vegetable and the animal; the

* This distinction of the two lives is bad, inasmuch as it tends to separate phenomena which have a very intimate connexion, which relate to a common object, and which are often produced by means in every respect similar. Why should I rank among the organs of animal life the muscular apparatus which carries the alimentary mass from the mouth into the oesophagus, and among those of the other life, that which takes it from the cardiac orifice to the anus? Is not the action of the first apparatus in relation with nutrition as well as the action of the last, and does not the muscular apparatus of the oesophagus act upon a body which is foreign to us, as well as that of the tongue and the pharynx? Do the motions of mastication differ in their object from

other belonging exclusively to the latter. In comparing two individuals from each of the living kingdoms, the one will be seen existing only within itself, having with what surrounds it the relations only of nutrition, attached to the soil, in which its seed has been implanted, born there, growing there, and perishing there. The other will be observed combining with this interior life, which in the highest degree it enjoys, an exterior life by which it acquires a very numerous series of relations with all surrounding bodies, a life, which couples it to the existence of every other being, by which it is approximated, or removed from the objects of its desires or its fears, and seems in appropriating every thing in nature to itself, to consider every thing with regard to its individual existence only.*

those of which we have just spoken, and as to the means of execution, does not the muscular action still perform the principal part?

We might in the same way bring near each other the motions by means of which we seize our food. The action itself of the senses, which directs these motions, is, with nutrition, in a relation more remote, but not less necessary, and we see in the various classes of animals that their apparatus is modified according to the different kinds of nourishment. If the distinction of the two lives be wanting in justice, as to the object of the functions it separates, we shall soon see that the characters attached to the organs of one and the other do not establish this division in a more striking manner.

* This division between vegetables and animals is far from being so striking as is here supposed; these two classes of beings, so different when we examine them in the individuals endowed with a very complicated organization, approximate each other in a remarkable degree, when we descend to those species whose structure is most simple; it is even remarkable that the most constant character which distinguishes one from the other, is not found in the organs of animal life, but in those of vegetable or organic life. The senses are one after the other found wanting; for in an individual in whom we can discover no nervous system, there is no more reason to suppose the existence of the sense of touch as a sensation, than to suppose it in the sensitive plant, the

Thus it might be said, that the vegetable is only the sketch, or rather the ground-work of the animal; that for the formation of the latter, it has only been requisite to clothe the former with an apparatus of external organs, by which it might be connected with external objects.

From hence it follows, that the functions of the animal are of two very different classes. By the one (which is composed of an habitual succession of assimilation and excretion) it lives within itself, transforms into its proper substance the particles of other bodies, and afterwards rejects them when they are become heterogeneous to its nature. By the other, it lives externally, is the inhabitant of the world, and not as the vegetable of a spot only; it feels, it perceives, it reflects on its sensations, it moves according to their influence, and

dionæa muscipula, and other similar plants; we see only action and reaction. The motions of the arms of certain polypi no more suppose volition than the motion of the root which follows a wet sponge, or that of the branches which turn towards the light; the only very constant character is the absence or presence of a digestive cavity. To speak of an animal as a vegetable clothed with an external apparatus of organs of relation, is a more brilliant than profound view of the subject. Buisson, who, in his division of the physiological phenomena, avoids this inaccuracy, has himself fallen into error; he pretends that respiration belongs exclusively to animals; and that thus the division of Bichat was not only unfounded but also incomplete, since this function, which is neither of vegetation nor of relation, could be ranked under neither life. Buisson was not well informed; no doubt the respiration of vegetables does not exhibit the most apparent phenomena of the respiration of the maunmalia, but every thing, which essentially constitutes the function, is found in the one as well as in the other; absorption of the atmospheric air, and the formation and exhalation of a new gas; the rest is only accidental and is not an appendage but in certain classes of animals. In some reptiles, though we find a particular organ for respiration, this organ is not indispensable; it may be removed, and the skin becomes the only respiratory organ; and when finally we come to consider animals with *tracheæ*, we see that the conformity becomes more and more evident.

frequently is enabled to communicate by its voice its desires, and its fears, its pleasures, and its pains.

The aggregate of the functions of the first order, I shall name the organic life, because all organized beings, whether animal or vegetable, enjoy it more or less, because organic texture is the sole condition necessary to its existence. The sum of the functions of the second class, because it is exclusively the property of the animal, I shall denominate the animal life.

The series of the phenomena of these two lives, relate to the individual. Generation, as a function, regards the species, and thus has no place among them. Its connections with the greater number of the other functions are but very indirect; it commences a long time after them, it is extinct a long time before them. In the greater number of animals the periods of its activity are separated by long intervals of time, and during these, it is absolutely null. Even in man, with whom the remissions of its impulses, are much less durable, it has not a much more extensive connexion with the rest of the system. Castration is almost always marked by a general increase of the nutritive process; the eunuch, enjoying indeed a less degree of vital energy, but the phenomena of his life being displayed with a greater exuberance. We shall here, then, lay aside the consideration of the laws which give us existence, and occupy ourselves alone on those which maintain us in existence. Of the former we shall speak hereafter.

II. *Subdivision of each of the two lives into two orders of functions.*

The animal and the organic life, are each of them composed of two orders of functions, which succeed each other, and are concatenated in an inverse direction.

In the animal life, the first order is established from the exterior of the body, towards the brain ; the second from the brain towards the organs of locomotion and the voice. The impression of objects successively affects the senses, the nerves and the brain. The first receive, the second transmit, the third perceives the impression. The impression, in such way, received, transmitted, and perceived, constitutes sensation.

The animal, in the first order of these functions, is almost passive ; in the second, he becomes active.—This second order is the result of the successive actions of the brain (where volition has been produced in consequence of the previous sensation) of the nerves, which transmit such volition, and of the locomotive organs and voice, which are the agents of volition. External bodies act upon the animal by means of the first order of these functions, the animal reacts upon them by means of the second.

In general there exists between the two orders a rigorous proportion ; where the one is very marked, the other is put forth with energy. In the series of living beings, the animal, which feels the most, moves also the most. The age of lively perception, is that also of vivacity of motion ; in sleep, where the first order is suspended, the second ceases, or is exercised only with irregularity. The blind man, who is but half alive to what surrounds him, moves also with a tardiness which would very soon be lost, where his exterior communications to be enlarged.

A double movement is also exercised in the organic life; the one composes, the other decomposes the animal. Such is the mode of existence in the living body, that what it was at one time it ceases to be at another. Its organization remains unaltered, but its elements vary every moment. The molecules of its nutrition by turns absorbed and rejected, from the animal pass to the plant, from the plant to inorganic matter, return to the animal, and so proceed in an endless revolution.

To such revolution the organic life is well adapted. One order of its functions assimilates to the animal the substances which are destined to nourish him; another order deprives him of these substances, when, after having for some time made a part of it, they are become heterogeneous to his organization.

The first, which is that of assimilation, results from the functions of digestion, circulation, respiration, and nutrition. Every particle, which is foreign to the body before it becomes an element of it, is subject to the influence of these four functions.

When it has afterwards concurred for some time to the formation of the organs, the absorbents seize on it, and throw it out into the circulatory torrent, where it is carried on anew, and from whence it issues by the pulmonary or cutaneous exhalations, or by the different secretions by which the fluids are ejected from the body.

The second order, then, of the functions of the organic life, or that of decomposition, is formed of those of absorption, circulation, exhalation, and secretion.

The sanguiferous system, in consequence, is a middle system, the centre of the organic life, as the brain is the centre of the animal life. In this system the particles, which are about to be assimilated, are circulated and intermixed with those, which having been already assimilated, are destined to be rejected; so that the blood itself is a fluid composed of two parts; the one, the pabulum of all the parts of the body, and derived from the aliment; the other, excrementitious, composed of the wrecks and residue of the organs, and the source of the exterior secretions and exhalations.—-Nevertheless these latter functions serve also, at times, the purpose of transmitting without the body, the products of digestion, although such products may not have concurred to the nourishments of the parts. This circumstance may be observed when urine and sweat are secreted after copious drinking. The skin and the kidneys being at such times the excreting organs, not of the mattter of the nutritive, but of that of the digestive process; the same also may be said of the milk of animals, for this is a fluid which certainly has never been assimilated.*

There does not exist between the two orders of the functions of the organic life the same relation, which takes place between those of the animal life. The weakness of the first by no means renders absolutely necessary a decrease of action in the second. Hence proceed marasmus and leanness, states, in which the

* Bichat seems here to adopt the generally received opinion that it is the chyle which furnishes to the mammary gland the materials of which the milk is composed. We know not whence this opinion arises, if it be not from the gross resemblance which the chyle and milk often exhibit. This resemblance, if it were very great, would be a poor reason for admitting, without anatomical proof, so singular a fact; but it is very far from being perfect. The chyle in fact does not exhibit the milky appearance and the white opake colour, only when the animal from whom it is taken, has fed upon substances containing fat; in all other cases, it is almost transparent; its odour and taste, under all circumstances, differ entirely from those of milk; if these two fluids are left to themselves, the milk remains a long time without coagulating, but the chyle almost immediately coagulates, and then separates into three parts. The solid portion soon exhibits cells, and an appearance of organization; nothing similar is seen in the cogulum of milk; the serum of the milk remains colourless when exposed to the simple contact of the air, that of the chyle assumes a rosy tint, often very vivid. Finally, if we examine the chemical composition of these two fluids, we shall find in them differences still more striking. (See for farther details, my Elements of Physiology, Vol. 2d.)

assimilating process ceases in part, the process of excretion remaining unaltered.

Let us leave, then, to other sciences, all artificial method, but follow the concatenation of the phenomena of life, for connecting the ideas which we form of them, and we shall perceive, that the greater part of the present physiological divisions, afford us but uncertain bases for the support of any thing like a solid edifice of science.

These divisions I shall not recapitulate; the best method of demonstrating their inutility will be, if I mistake not, to prove the solidity of the division, which I have adopted. We shall now examine the great differences, which separate the animal existing without, from the animal existing within, and wearing itself away in a continual vicissitude of assimilation and excretion.

CHAPTER II.

GENERAL DIFFERENCES OF THE TWO LIVES WITH REGARD TO THE OUTWARD FORM OF THEIR RESPECTIVE ORGANS.

The organs of the animal life are symmetrical, those of the organic life irregular in their conformation; in this circumstance consists the most essential of their differences. Such character, however, to some animals, and among the fish, to the sole and turbot especially, is not applicable; but in man it is exactly traced, as well as in all the genera which are nearest to him in perfection. In them alone am I about to examine it.

I. *Symmetry of the external forms of the animal life.**

Two globes in every respect the same, receive the impressions of light. Sounds and odours, have also their double analogous organ. A single membrane is affected to savours, but the median line is manifest upon it, and the two segments, which are indicated by it, are exactly similar. This line indeed is not every where to be seen in the skin, but it is every where implied. Nature, as it were, has forgotten to describe it, but from space to space she has laid down a number of points, which mark its passage. The cleft at the extremity of the nose, of the chin, and the middle of the lips, the umbilicus, the seam of the perineum, the projection of the spinous apophyses of the back, and the hollow at the posterior part of the neck are the principal points at which it is shewn.

The Nerves, which transmit the impressions received by the senses, are evidently assembled in symmetrical pairs.

* It is rather to the external forms that symmetry appears to have been primitively attached, and it is in some measure accidentally and because the nature of their functions requires in general that they should be placed on the exterior, that the organs of relation are found modified in virtue of this law. In the example cited, of fishes without a bladder, the eyes, to lose nothing of their utility, must be differently placed, and on the face, which alone is in relation with the light; yet even in this case, the symmetry of external forms has been displaced rather than destroyed, and at the first examination it seems complete. When the organs of relation are found placed on the interior, they frequently exhibit some irregularity, and to take an example of a known animal, the organ of voice, in the male duck, is a very remarkable one; in man even, the wind-pipe is not symmetrical, after it arrives at the first division of the bronchia. On the contrary, among the organs of the other life, those which are prominent on the exterior, constantly present the symmetrical character, as the thyroid gland, the mammary glands, &c.

The brain, the organ (on which the impressions of objects are received) is remarkable also for the regularity of its form. Its double parts are exactly alike, and even those which are single, are all of them symmetrically divided by the median line.

The Nerves again, which transmit to the agents of loco-motion and of the voice, the volitions of the brain, the locomotive organs also, which are formed in a great degree of the muscular system, of the bony system, and its dependencies, these together with the larynx and its accessaries, composing the double agents of volition, have all of them a regularity, a symmetry, which are invariable.

Such even is the truth of the character which I am now describing, that the muscles and the nerves immediately cease to be regular, as soon as they cease to appertain to the animal life. The heart, and the muscular fibres of the intestines are proofs of this assertion in the muscles; in the nerves, the great sympathetic, is an evidence of its truth.

We may conclude then from simple inspection, that Symmetry is the essential character of the organs of the animal life of man.

II. *Irregularity of the exterior forms of the organic life.*

If at present we pass to the viscera of the organic life, we shall perceive a character directly the contrary of the former. The stomach, the intestines, the spleen, the liver, &c. are all of them irregularly disposed.

In the system of the circulation, the heart and the large vessels, such as the upper divisions of the aorta, the vena azygos, the vena portæ, and the arteria innominata have no one trace of symmetry. In the vessels of the extremities continual varieties are also observed, and when they occur, it is particularly remarkable that their existence on one side in no way affects the other side of the body.

The apparatus of respiration appears indeed at first to be exactly regular; nevertheless, the bronchi are dissimilar in length, diameter, and direction; three lobes compose one of the lungs, two the other: between these organs also, there is a manifest difference of volume; the two divisions of the pulmonary artery resemble each other neither in their course, nor in their diameter; and the mediastinum is sensibly directed to the left. We shall thus perceive that symmetry is here apparent only, and that the common law has no exception.

The organs of exhalation and absorption, the serous membranes, the thoracic duct, the great right lymphatic vessel, and the secondary absorbents of all the parts have a distribution universally unequal and irregular.

In the glandular system also we see the crypts, or mucous follicles disseminated in a disorderly manner in every part; the pancreas, the liver, the salivary glands themselves, though at first sight more symmetrical, are not exactly submitted to the median line; added to this, the kidneys differ from each other in their situation, in the length and size of their artery and vein, and in their frequent varieties more especially.*

* If we deny symmetry to the kidneys, because they are not uniformly composed of the same number of lobes in children, we must deny it also to the brain, the two lobes of which never exhibit the same arrangement in their circumvolutions; if we deny it to the salivary glands, because one is larger than the other, we must deny it to the extremities, because the right is usually more developed than the left. If these examples are not enough, a host of others might be cited; such as, the atrabiliary capsules, the bladder, the different organs of generation and lactation, and the very regular arrangement of the mucous

From considerations so numerous we are led to a result exactly the reverse of the preceding one; namely, that the especial attribute of the organs of the interior life is irregularity of exterior form.

III. *Consequences resulting from the difference of exterior form in the organs of the two lives.*

It follows from the preceding description, that the animal life is as it were double; that its phenomena performed as they are at the same time on the two sides of the body, compose a system in each of them independent of the opposite system; that there is a life to the right, a life to the left; that the one may exist, the other ceasing to do so, and that they are doubtless intended reciprocally to supply the place of each other.

The latter circumstance we may frequently observe in those morbid affections so common, where the animal sensibility and mobility are enfeebled, or annihilated on one side of the body, and capable of no affection whatever; where the man on one side is little more than the vegetable, while on the other he preserves his claim to the animal character. Undoubtedly those partial palsies, in which the median line, is the limit where the faculties of sensation and motion finish, and the origin from whence they begin can never be remarked so invariably in animals, which, like the oyster, have an irregular exterior.

On the contrary the organic life is a single system, in which every thing is connected and concatenated; where

follicles in certain parts situated upon the median line, &c. As to the anomalies that are observed in the distribution of the blood-vessels, they are also observed very frequently, though in a less evident manner, in the distribution of the nervous branches.

the functions on one side cannot be interrupted, and those on the other subsist. A diseased liver influences the state of the stomach; if the colon on one side cease to act, that upon the other side cannot continue in action: the same attack, which arrests the circulation in the right side of the heart, will annihilate it also in the left side of the heart. Hence it follows, the internal organs on one side being supposed to suspend their functions, that those on the other must remain inactive, and death ensue.

This assertion, however, is a general one; it is only applicable to the sum of the organic life, and not to its isolated phenomena. Some of them in fact are double, and their place may be supplied—the kidneys and lungs are of this description.

I shall not enquire into the cause of this remarkable difference, which in man, and those animals which approach him the nearest, distinguishes the organs of the two lives. I shall only observe, that it enters essentially into the nature of their phenomena, and that the perfection of the animal functions is so connected with the general symmetry observed in their respective organs, that every thing which troubles such symmetry, will more or less impair the functions.

It is from thence, no doubt, that proceeds this other difference of the two lives, namely, that nature very rarely varies the usual conformation of the organs of the animal life. Grimaud has made this observation, but has not shewn the principle on which it depends.

It is a fact, which cannot have escaped any one the least accustomed to dissection, that the spleen, the liver, the stomach, the kidneys, the salivary glands, and others of the internal life, are frequently various in form, size, position, and direction. Such in the vascular system are these varieties, that scarcely will any two subjects be found exactly alike under the scalpel of the anatomist: the organs of absorption, the lymphatic glands in particular, are rarely the same either in number or volume, neither do the mucous glands in any way affect a fixed and analogous situation.

And not only is each particular system subject to frequent aberrations, but the whole of the organs of the internal life are sometimes found in the inverse of the natural order. Of this I have lately seen an instance.

Let us now consider the organs of the animal life, the senses, the brain, the voluntary muscles, and the larynx: here every thing is exact, precise, and rigourously determined. In these there is scarcely ever seen a variety of conformation; if there do exist any, the functions are troubled, disturbed, or destroyed: they remain unaltered in the organic life, whatever may be the disposition of the parts.

The difference with respect to action, in the organs of the two lives, depends, undoubtedly, upon the symmetry of the one, whose functions the least change of conformation would have disturbed, and on the irregularity of the other, with which these different changes very well agree.

The functions of every organ of the animal life are immediately connected with the resemblance of the organ to its fellow on the opposite side if double, or if single to its similarity of conformation in its two halves: from hence the influence of organic changes upon the derangement of the functions may be well conceived.

But this assertion will become more sensible, when I shall have pointed out the relations which exist between the symmetry and the irregularity of the organs, and the harmony and the discordance of their functions.

CHAPTER III.

GENERAL DIFFERENCE OF TH TWO LIVES WITH REGARD TO THE MODE OF ACTION OF THEIR RESPECTIVE ORGANS.

Harmony is to the functions of the organs, what symmetry is to their conformation; it supposes a perfect equality of force and action, between their similar parts, just as symmetry indicates an exact analogy of external form, and internal structure: indeed it is a necessary consequence of symmetry, for two parts essentially alike in structure, cannot much differ in their manner of action. Hence we should be naturally led to the following conclusion, namely, that harmony is the character of the animal, discordance that of the organic functions. But on these points we must be more particular.

I. *Of harmony of action in the animal life.*

We have already observed, that the animal life arises from the successive actions of the senses, the nerves, the brain, the locomotive organs, and the voice. We shall now consider what harmony of action is, in each of these great divisions.

The precision of our sensations appears to be the more complete in proportion as there exists a resemblance between the two impressions, of which they are each of them the assemblage. We see inaccurately when one of the eyes is better formed, and stronger than the other; when it conveys to the brain a clearer image than its fellow does. It is to avoid this confusion that we shut one eye, while the action of the other is increased by the application of a lens, for at such time there can be no harmony of action in the two organs; accordingly, we make use of one of them only in order to avoid the discordance of the impression.—What a lens applied to one eye only produces artificially, is exemplified in a natural way by squinting.—We squint, says Buffon, because we turn the weaker eye from the object on which the stronger is fixed; for in so doing we avoid the confusion, which would arise from the perception of two dissimilar images.

We know that many other causes may contribute to the production of this effect, but we cannot doubt the reality of the reason assigned. We know also, that in some animals each eye may act without the assistance of the other, and that two different objects may be transmitted at the same time by the two eyes of certain other animals; but this circumstance, when the action of both the organs is united upon a single object, should by no means prevent a similarity in the two impressions. A single sensation is the consequence of the combination; but in what way can such sensation be formed with accuracy, if the same body at the same time be pictured both in strong and weak colours on the one and the other of the retinæ?

What we have said of the eye may be equally well applied to the ear. If, of the two sensations which form a sound, the one be received by a strong and well formed organ, the other by a weak one, the impressions will be unequal; the brain also, because it is differently affected by each, will be the seat of an imperfect perception. Such conformation constitutes what is called an incorrect or false ear. For what reason does it happen that one man is unpleasantly affected by a dissonance, while another does not even perceive it? The reason is this, that in the one, the two perceptions of the same sound are identical; in the other, dissimilar.* For the same reason a man with a correct ear will combine his dancing with the cadence of the measure given him; another without this similarity of organ will be as constantly at variance in his motions with the orchestra.

Buffon has confined his observations on harmony of action, to the organs of vision and hearing; we shall push our examination of it farther.

In the sense of smelling, as well as in the other senses, we must admit of two impressions; the one primitive, and belonging to the organ, the other consecutive, and affecting the sensorium: now the latter may vary, the former remaining unaltered. Many odours are disagreeable to some, but pleasant to others; and this, not because there is any difference in the affection of the pituitary membrane, but because in different individuals, the mind may attach a very different sentiment to the same impression.—Hence a variety of results does not in this case suppose a difference of principle.

But sometimes the impression which is made upon the pituitary membrane does really differ from that which it ought to be, for producing perfect sensation. Two dogs pursue the same game; the one never loses scent, but makes the same turnings and windings with the animal

* This supposition, though no doubt ingenious, is not true. If the want of accuracy of hearing arose in fact from the inequality of the power of the two organs, this defect might be remedied by using but one ear; but experience gives a different result. We shall not discuss, in relation to the same principle of inequality of the organs, the explanation of strabismus; but at least, for every thing that relates to the just appreciation of colours, this principle is no more applicable than to the just appreciation of sounds. I know a man who has never been able to distinguish the *blue of the sky* from *the green of the sea*, and he succeeds no better by closing one eye.

before him; the other follows his game also, but often stops and hesitates, endeavors to recover the scent, proceeds and stops again. The first of these receives a lively impression of the scented emanation; the organs of the second are only confusedly affected. Now it may be asked whether this confusion does not arise from the unequal action of the two nostrils, from the superior organization of the one, and from the imperfection of the other?—the following observations appear to decide the question.

In the coryza, which affects but one of the nostrils, if the two be suffered to remain open, the sense of smelling is confused; but let the diseased nostril be shut, and the smell shall immediately become distinct. A polypus in one of the nostrils debilitates the action of the pituitary membrane on the affected side, the other remaining in its healthy state: hence, as in the preceding case, ensues a want of harmony in the two organs, and the same confusion in the perception of odours. The greater number of the affections of a single nostril have similar effects, which may be all of them corrected by the same means. And wherefore? because in rendering one of the pituitary membranes inactive, we put a stop to the discordance which is occasioned by the deficiency of action in the other. From the above facts (since any accidental cause, which destroys the harmony of action in these organs, is capable of rendering the perception of odours inexact) we may conclude, that when the perception is naturally inaccurate, there is a natural dissimilarity in the formation of the organs, and therefore a difference of power in them.

The same reasoning may be applied to the sense of taste. It is often the case that one side of the tongue is affected by palsy or spasm, the median line dividing the insensible half from the other, which continues to preserve its sensibility. But such affection may take place in a variety of degrees, and one side of the tongue retain a power of perceiving savours though in a less perfection than the other side. In such case it is natural to suppose that the taste must be confused; because a clear perception cannot be the consequence of two unequal sensations.

The perfection of the touch as well as that of the other senses, is essentially connected with uniformity of action in the two symmetrical halves of the body, and particularly in the hands. Let us suppose, for instance, a man born blind, to have one hand well organized, the other defective in the power of moving the thumb and fingers, and forming only a stiff and immovable surface; such person would find it a very difficult thing to acquire a just notion of the size and figure of bodies, because the same sensation would not arise from the successive application of each hand to the same substance. Let both of his hands, for example, be supposed to touch a small sphere; the one by the extremities of the fingers will embrace it in all its diameters, and convey to him the idea of roundness; the other, which will be in contact with it only in a few points, will produce a very different sensation. Embarrassed between these two bases of his judgment, he will scarcely be able to decide, nay, it is even possible that he may form a double judgment from the double sensation which is presented him: his ideas would be more correct were he to use only the perfect hand, in the same manner as the person who squints, makes use of the perfect eye only. Our hands then assist each other reciprocally; the one confirms the notions which are given us by the other; hence the necessary uniformity of their conformation.

The hands are not the only instruments of the sense of touch. The axilla, the groin, the concavity of the foot and many other parts, may all of them from their application to bodies, afford us so many bases for our judgments with regard to external form. Now, if one half of the body were differently arranged from the other half, the same uncertainty in perception would infallibly be the result. From all that has been said, we may conclude, that in the external organs of sense, a harmony of action in the two symmetrical parts, or the two similar halves of the organ, is a condition essential to the perfection of sensation.

The external senses are the natural excitants of the brain. The functions of the brain succeed to theirs, and this organ would but languish, were it not to find in them the principle of its activity. From sensation follow perception, memory and imagination; from these the judgment. Now it is easy to prove, that these different functions, commonly known by the name of the internal senses,* are governed in their actions by the same laws, which influence the external senses; and that like them, they approach the nearer to perfection in proportion to the degree of harmony existing in the symmetrical parts, in which they have their seat.

Let us suppose for instance one hemisphere of the brain to be better organised, and therefore susceptible of livelier affections than its fellow; in such case the perception of the individual would be confused, for the brain is to the soul what the senses are to the brain; it transmits

* We cannot, without confounding all the ideas we have formed of the senses, give this name to the memory, imagination and judgment; at the most we might give the name of internal senses to certain sensations which inform us of the particular state of some internal organ, in the same way as the external senses make us acquainted with the properties and state of external bodies.

to the soul the impressions conveyed to it by the senses, as the senses convey to the brain the impressions made upon them by external objects. But, if the defect of harmony in the external senses confuse the perception of the brain, why may not the soul perceive but confusedly, when the two hemispheres of the brain are unequal in power, and incapable of blending into one the double impression, which is made upon them ?

The memory is the faculty of re-producing former sensations, the imagination that of creating new ones, now in the act of remembering or imagining, each hemisphere of the brain appears to re-produce, or to create a sensation of its own. If both do not act alike, the perception of the mind, which ought to be the result of the two sensations united, will be inexact and irregular. But, it is evident, that there will be a disparity in the two sensations, if there be a disparity in the two halves of the brain, in which they have arisen, and since the general foundations of the judgment are made up of the faculties of perception, memory, and imagination, if these be confused, the judgment itself must be confused also.

We have now supposed an inequality of action in the hemispheres of the brain, and inferred, that the functions would in this supposition be imperfect ; but what as yet is only supposition, in a variety of instances can be proved to be a fact ; for nothing is more common than to find in consequence of compression on either hemisphere by blood, pus, or exostosis, a variety of alterations in the intellectual functions.

Even when all appearances of actual compression have vanished, if in consequence of that which has been experienced, a part of the brain remain enfeebled, the same alterations of mental power will be found to be prolonged. If both hemispheres of the brain, however, be affected equally, the judgment though weaker, will be more exact.* Perhaps it is thus, that we should explain those observations so frequently repeated, of an accidental stroke upon one side of the head having restored the intellectual functions, which had long remained dormant in consequence of a blow received upon the other side.

I now conceive myself to have proved, that with inequality of action in the hemispheres, there must be confusion of intellect. I have also pointed out some states of disease, in which such confusion is evidently the effect of inequality of action so occasioned; here we see the effect and its cause; but may we not from analogy, infer a similar cause where we see a like effect? when the judgment is habitually incorrect, and all the ideas wanting in precision, may we not be induced to believe, that there does exist a defect of harmony in the action of the two hemispheres of the brain? We see inaccurately if nature have not given to both eyes an equal power; we perceive and judge inaccurately in like manner, if the two sides of the brain are naturally dissimilar. The most correct mind, and the soundest judgment, pre-suppose in the hemispheres a perfect harmony of action; and what a multiplicity of shades do we not behold in the operations of the understanding? it is probable that they all of them correspond to so many varieties in the proportions of power in the hemispheres. Could we squint with the brain as we do with the eyes—that is to say, could we

* We cannot conceive how the judgment can be weak or strong, if we do not understand by it that it is habitually accurate or inaccurate. His judgment is sound who usually perceives the true relations between things; and this is independent of the number and variety of the ideas upon which he has to pronounce. The man to whose mind there is presented but a small number of relations, has but little imagination; but if these relations be true, we cannot say that his judgment is weak.

receive impressions on one hemisphere only, and form from thence our determinations, we might then command at will, a precision in our intellectual operations; but such a power does not exist.

To the functions of the brain succeed those of locomotion and the voice. The first of these would appear almost to form an exception to the general law. In considering the two vertical halves of the body, we shall perceive that the one is constantly more powerful than the other with respect to the strength and number of its movements. The right half is that, which from custom, is most made use of.

To comprehend the reason of this difference; we must make a differerence between strength and agility; strength depends upon the perfection of the organization, on the energy of the nutritive process, on the plenitude of life in the muscular fibre; agility, on the contrary, is the result of habit and frequent exercise.*

* Bichat, in order to retain for the organs of organic life the character of irregularity in the forms which he had assigned to them, has been compelled to avail himself of the inequality of the size of the congenerous organs. He soon repented having established an uniform principle; and in this case for example, he is near being condemned by the very sentence which he has himself pronounced The locomotive system, in fact, the symmetry of which no person before him thought of denying, is destitute of it according to the principle he has established, since it presents in its two halves an inequality of size and action. In order to avoid this consequence, Bichat has maintained that the inequality of size arose from the inequality of action, and that this was the result, not of an original disposition, but of our social habits only. To prove this assertion, he has been compelled to heap sophism on sophism ; he cannot in this case be suspected of a wish to deceive; he was convinced of the truth of the principle, and we know that to prove what is believed to be true, the weakest reasons always seem to be sufficient. But these very errors should be turned to our advantage, by showing us how dangerous is the tendency of generalizing

At present we shall observe, that this disparity of action in the locomotive organs, does not consist in the difference of their actual strength, but in that of the agility, with which these motions are executed.—All is equal in the size, in the number of fibres, and nerves both of the one and the other of the superior, or inferior extremities; the difference of their vascular systems is scarcely any thing. From hence it follows that the discordance does not exist in nature, but that it is the effect of our social habits, which by multiplying our movements on one side of the body, increase their address without much adding to their power. Such in fact are the wants of society, as to call forth a certain number of general movements, which must be performed by all in the same direction, in order to be understood. It is generally agreed, that this direction shall be from

upon every thing, since it was capable of misleading so judicious a mind.

Without stopping to refute in detail all the reasons which he has advanced to support his opinion, we cannot help saying something of them; and in the first place, the difference of size uniformly exists; it is evident that it does not arise from great exercise, since it is found in the infant at birth, and the nourishing artery of the right arm is larger than that of the left. If the right arm be not really stronger than the other, why should we always use it in preference? If we employ it in writing, should we say with Bichat, that it is only because it is better situated to move from left to right, in the order in which the characters of our writing succeed each other; might it not be said, with more reason, that our letters go from left to right, because it is the direction in which the right hand most easily traces them? All this besides relates merely to the form of our characters, since all the oriental languages are written from right to left; yet it is always done with the right hand. Is it still said that the necessity of union in battle has led to the employment of the right arm to hold the weapons, as if the Hurons or Algonquins fought in close ranks like our Grenadiers. If this use of the same arm or the same leg was only conventional, why among some people, is the left side never preferred?

left to right. The letters, which form the writing of most nations, are in this way directed; such circumstance occasions the necessity of our using the right hand to form them in preference to the left, the former being as much better adapted to this method, as the latter would be to the contrary one; of this we may convince ourselves by experiment.

The direction of the letters from left to right, imposes on us the necessity also of casting our eyes upon them in the same direction. From this habit acquired in reading, arises that of examining objects in the same manner.

The necessity of similar movements when men are drawn up in line of battle, has induced almost all nations to handle their weapons with their right hands; the harmony too which prevails in the dances of even the most savage people exacts an accord in the limbs, which they constantly preserve by making all their principal movements with the right. We might add to these examples a great variety of others.

The general movements agreed on by society, which, if every one were not to execute them in the same direction, would be creative of much confusion; these movements, I say, by the influence of habit, oblige us for our own particular movements to use the limbs, which they have brought into action. Hence, the members of the right side of the body are perpetually in action either for our own particular wants, or for those which we feel in conjunction with others.

Now, as the habitude of acting, continually tends to the perfection of action, we may perceive the reason, why the right side acquires a greater facility in the performance of many motions than the left. This increased facility is not original, but acquired.

So remarkable a difference then, in the two symmetrical halves of the body, is not by nature meant as an exception to the general law of harmony of action in the external functions; for those movements, which are executed by the whole of the body, are the more precise in proportion to the smallness of the difference existing in the agility of the muscles of the two sides. How happens it that certain animals leap from rock to rock with such admirable precision, where the least deviation from the intended direction, would plunge them into an abyss? how happens it that they run with such astonishing address on planes, which are scarcely equal in breadth to the extremities of their limbs? how happens it that the walk of the very heaviest of animals is never attended with those false steps so frequent in the progression of man? The reason must be, that the difference in their locomotive organs in both sides of the body is scarcely any thing, and that in consequence there must be a constant harmony of action in these organs.

He, whose general movements, or those of the whole of the body are the most perfect, has the least command in particular over those of the right side; for, as I shall prove hereafter, the perfection of a part is never acquired but at the expence of that of the whole. The child, who should be taught to make an equal use of all his limbs, would possess a precision in his general movements, which he would find extremely difficult to acquire for those of the right hand, such as writing or fencing.

I can easily suppose, that some few natural circumstances may have exercised upon us an influence in our choice with respect to the direction of those general motions, which the habits of society have established. Such may be the slight excess of diameter in the right subclavian artery, and the sensation of lassitude during digestion, which is more perceived upon the left side on account of the situation of the stomach, and may therefore have determined us to act at such time upon the opposite side in preference. Such also may be the natural instinct, by which, to express our feelings we carry the right hand to the heart; but these circumstances are trifling in comparison with the very great difference of the movements which from the state of civilization exists between the symmetrical halves of the body; and from this view of the subject, we cannot but regard this difference as the effect of social convention, and by no means the intent of nature.

The voice, together with locomotion, is the last act of the animal life in the natural order of its functions. Now the greater number of physiologists, and Haller in particular, have indicated as the causes of want of harmony in the voice, the dissimilarity of the two portions of the larynx, the inequality of force in the muscles, which move the arytenoid cartilages, the same inequality of action in the nerves, which are distributed to each half of the organ, and the different reflection of sounds in the nostrils and frontal sinuses. Without doubt a defective voice must frequently depend upon a faulty ear; when we hear incorrectly, we sing incorrectly; but when a correct ear is united with a want of precision in the voice, the cause is then in the larynx.

The most harmonious voice is that, which the two portions of the larynx produce in an equal degree; where the vibrations on one side correspond exactly in number, strength and duration with those upon the opposite side.*

* The theory of wind instruments is not yet sufficiently well understood, to enable us to say, what sort of influence would be exerted upon the sound by the inequality of vibrating plates.

(See the article Voice, in my Elements of Physiology, Vol. 2d.)

In the same manner the most perfect singing will be produced by two voices exactly similar in tone, compass, and inflection.

From the numerous considerations which I have offered, the following general conclusion may be deduced—namely, that one of the most essential characteristics of the animal life, is a harmony of action in the two analogous parts, or in the two sides of the simple organ concurring to the same end. The relation which exists between this harmony of action, which is the character of the functions, and symmetry of form, which is the attribute of the organs of the animal life, will easily be seen.

I wish to observe in finishing this section, that in pointing out the different derangements, which take place in the animal life, from the want of harmony in the organs, I have only pretended to assign a single isolated cause of such derangements; I am well aware that a thousand other causes besides dissimilarity in the hemispheres of the brain, may affect the operations of the mind.

II. *Of discordance of action in the organic life.*

Along with the phenomena of the animal life, let us now consider those of the organic life, and we shall find that harmony has nothing to do with them. Of what detriment would it be to the general health of the individual, should one of his kidneys be stronger than the other, and secrete more urine; should one of his lungs be better unfolded than the other, admit more venous, and send out more arterial blood; should a less organic force be the lot of the salivary glands on one side than on the other side of his body? The simple function, to which both organs concur, would not be performed less perfectly. Whenever but a slight fulness supervenes on one side of the liver, spleen, or pancreas, the sound part makes up for the defect, and the function is little disturbed. The circulation also remains unaltered among the frequent variations in the vascular system of each side of the body, whether such variations exist naturally, or whether they arise from some artificial obliteration of the larger vessels as in aneurism.

Hence we find those numerous irregularities of structure, those malconformations, which as I have said may be remarked in the organic life, and nothing of a morbid nature in consequence arising. From hence we see that almost continual succession of modifications, which lessen or increase the circle of the organic functions. The vital powers, and their exciting causes, are continually varying, and thus occasion a constant instability in the functions of the organs, for a thousand causes may at every moment double or triple the activity of the circulation, and respiration, increase or diminish the quantity of bile, urine, or saliva, and suspend or augment the nutrition of the parts. Hunger, food, sleep, motion, rest, and the passions may all of them impress upon these functions so great a mobility, as every day to make them run through a hundred degrees of strength or weakness.

In the animal life on the contrary, every thing is uniform and constant, the powers of the senses cannot experience these alternate modifications, or at least, not in so marked a manner. Indeed they are at all times in a state of relation with the physical powers, which preside over exterior bodies; now the latter remaining unaltered, such variations would destroy all relative connexion, and thus the functions cease.

Besides, if this mobility, which characterises the organic life, were the attribute of sensation—for the same reason it would be that of all the operations of the mind. In such case of what would man consist? The perpetual sport of every thing surrounding him, he would find his existence at one time little different from that of inanimate matter, at others superior in perfection and energy to that even which he now enjoys, allied at one time to the brute, at another, to spiritual nature.

CHAPTER IV.

GENERAL DIFFERENCES OF THE TWO LIVES WITH RESPECT TO DURATION OF ACTION.

One of the great distinguishing characters of the phenomena of the animal life in opposition to those of the organic life, has just been shewn. That, which I am about to examine, is not of less importance. The functions of the animal life intermit; the functions of the organic life are performed with an uninterrupted continuity.

I. *Of continuity of action in the organic life.*

Prolong but little the causes which are capable of suspending respiration, or the circulation of the blood, and life itself shall be suspended, nay, even annihilated. All the secretions go on uninterruptedly; if they intermit at all (and those of the bile and saliva for instance, when not immediately required for the purposes of digestion and mastication, may be said to intermit) such intermissions affect the intensity of the secretion only, and not the entire exercise of the function. Exhalation and absorption incessantly succeed each other; the process of nutrition must be continually carried on; the double movement of assimilation and decomposition from which it results, can only be terminated with life itself.

In this concatenation of the organic phenomena, each function depends immediately upon those which precede it. The centre of them all, the circulation, is immediately connected with the exercise of them all, for when this is troubled, they languish, when this ceases, they cease also. Just in the same manner the movements of a clock all stop with the pendulum. Nor only is the general action of the organic life connected with the heart; but there cannot exist a single function of this nature unconnected with all the others, for without secretion, there can be no digestion, without exhalation no absorption, without digestion no nutrition. Hence as a general character of the organic functions may be indicated continuity of action, and mutual dependence.

II. *Of intermission of action in the organic life.*

In the exercise of the functions of the animal life, there will be regularly seen an alternation of activity and repose, complete intermissions, and not remissions only.

Fatigued by long continued action, the senses all alike become for a time, incapable of receiving any further impression. The ear loses its sensibility to sound, the eye to light, the tongue to savours, the pituitary membrane to smells, the touch to the qualities of bodies about which it is conversant, and all this for the sole reason that the respective functions of these different organs, have for a long time been exercised.

In like manner, the brain fatigued by too great an effort in the exercise of any of its powers, in order to regain its excitability, must cease to act for a period proportioned to the duration of its preceding action. The muscles also after having been strongly contracted, before they can contract anew, must remain for awhile in a state of relaxation. Hence in locomotion, and the exertion of the voice, there must be intermissions.

Such then is the character peculiar to the organs of the animal life. They cease to act because they have acted. They become fatigued, their exhausted powers must be renewed.

This intermission is sometimes general, sometimes partial. When a single organ, for a long time, has been exercised, the others remaining inactive, it relaxes and sleeps, the others continuing to watch.—Hence, without doubt, proceeds the reason, why there is no immediate dependence among the functions of this order on each other. The senses being shut up against sensation, the brain may still subsist in action, may remember, imagine, or reflect. In such case the power of locomotion and the voice also, may equally well be exercised, and these in like manner may remain unexercised, and the activity of the senses be in no-wise impaired.

Thus the animal at will may fatigue any one of the parts of this life, and on this very account, such parts must all of them possess a capability of being relaxed, a power of repairing their forces in an isolated manner. This is the partial sleep of the organs.

III. *Application of the law of intermission of action to the theory of sleep.*

General sleep is the sleep of all the parts. It follows from that law, which with respect to the functions of the animal life, enchains intermission with periods of action, from that law, by which this life is particularly distinguished from the organic life.

Very numerous varieties are remarked in this periodical state, to which all animals are subject. The most complete sleep is that in which the outward life is entirely suspended. The least perfect sleep is that which affects one organ only; it is that of which we have just been speaking.

Between these two extremes there are many intermediate states. At times perception, locomotion, and the voice only are suspended; the imagination, the memory, and the judgment remaining in action. At other times, to the exercise of the latter faculties are added those of the locomotive organs and the voice.—Such is the sleep, in which we dream, for dreams are nothing more than a portion of the animal life escaped from the torpor, in which the other portion of it is plunged.

Sometimes but very few of the senses have ceased their communication with external objects. Such is that species of somnambulism, in which to the action of the brain, the muscles, and the larynx, are added the very distinct actions of the ear and the sense of touch.*

* The action of the brain is far from being preserved in somnambulism. The thread of ideas, on the contrary, is completely broken, and this is the most striking character which distinguishes every kind of sleep from wakefulness. The mind then cannot reflect upon the sensations which it receives, it abandons itself successively and without any resistance to all those which are presented, without examining the connexion which they can have between them. In ordinary sleep, the senses are almost entirely blunted, the mind receives no other sensations than those which have been derived from memory; but they present themselves in a confused manner, without order and in such a way as often to form the most strange and incoherent images. In somnambulition the action of many senses, and that of hearing in particular is preserved; the judgment of the sleeper can then exercise itself not only upon its reminiscences, but also upon the impressions

Sleep then cannot be considered as a constant and invariable state with regard to its phenomena.—Scarcely ever do we sleep in the same manner twice together. A number of causes modify in applying to a greater or less portion of the animal life the laws of intermission of action. Its different degrees should be marked by the different functions, which these intermissions affect.

But the principle of it is every where the same from the simple relaxation of a muscle to the entire suspension of the whole of the animal life. Its application, however, to the different external functions, varies without end.

These ideas on sleep are different, no doubt, from that narrow system, where its cause exclusively placed in the brain, in the heart, in the large vessels, or in the stomach, presents an isolated and frequently an illusory phenomenon, as the base of one of the great modifications of life.

And what is the reason why light and darkness in the natural order of things, coincide so regularly with the activity or intermission of the external functions? The reason is this, that during the day a thousand means of excitement perpetually surround the animal, a thousand causes exhaust the powers of his sensitive and locomotive organs, fatigue them, and prepare them for a state of relaxation, which at night is favoured by the absence of every kind of stimulus. Thus, in the actual state of

which are transmitted to it from without. The sound of a bell or a drum, being heard while we are in a dream, will immediately modify it. In this way a person may gain the attention of a somnambulist, and as the latter possesses the use of his voice, it will be seen by his answers that his ideas can be directed at will, and led in this way wherever it is wished; for the impressions that he receives from without, being stronger than those which come from memory, he will almost always obey the first.

society, where this order is in part inverted, we assemble about us at evening, a variety of excitants, which prolong our waking moments, and put off until towards the first hours of daylight, the intermission of our animal life, an intermission, which we favour besides by removing from the place of our repose whatever might produce sensa-ion.

We may for a certain time, by multiplying the causes of excitement about them, withdraw the organs of the animal life from this law of intermission, which should naturally cause them to sleep; but at last they must undergo its influence, and nothing can any longer suspend it. Exhausted by watching, the soldier slumbers at the cannon's side, the slave under the whip, the criminal in the midst of torture.

We must carefully make a distinction, however, between the natural sleep, which is the effect of lassitude, and that, which is the consequence of some affection of the brain, of apoplexy, or concussion, for instance. In the latter case the senses watch, receive impressions, and are affected as usual, but these impressions are not perceived by the diseased sensorium; we cannot be conscious of them. On the contrary, in ordinary sleep the senses are affected as much, or even more than the brain.

From what has now been said, it follows, that the organic life, has a longer duration than the animal life. In fact the sum of the periods of the intermissions of the latter, is almost equal to that of the times of its activity. We live internally almost double the time that we exist externally.

CHAPTER V.

GENERAL DIFFERENCES OF THE TWO LIVES WITH RESPECT TO HABIT.

ANOTHER of the great distinguishing characters of the two lives of the animal, consists in the independence of the one, and in the dependence of the other on habit.

I. *Of habit in the animal life.*

In the animal life every thing is modified by habit. The functions of this life, whether enfeebled or exhausted by it, according to the different periods of their activity, appear to assume a variety of characters : to estimate the influence of habit, it is necessary to consider two things in the effect of all sensation, the sentiment, or immediate feeling, which we have of external objects, and the judgment which is the result of one or more comparisons made with respect to them. An air, for instance, strikes the ear ; the first impression made upon the organ is, we know not why, agreeable or painful. This is sentiment— at present let us suppose the air to be continued. We may now endeavour to appreciate the different sounds of which it is composed, and to distinguish their accords. In this we exercise the judgment. Now, on these two things, the action of habit is inverse. It enfeebles our sentiment of things, it improves our judgment of them ; the more we regard an object, the less are we sensible of its agreeable or painful qualities, the better, at the same time, may we judge of its attributes.

II. *Habit blunts the sentiment.*

Let us dwell a little on the foregoing proposition; we have said that it is the property of habit to enfeeble our sentiments of things, to bring us into a state of indifference, the middle term betwixt pain and pleasure. But before we set about to prove an assertion so remarkable, it will be well to fix the sense of it with some precision. Pain and pleasure are absolute and relative.* The instrument which tears us in pieces is a cause of absolute pain. Sexual connexion is a pleasure of the same nature. Again, the view of a beautiful country delights us, but here the enjoyment is relative to the actual state of the mind only; its charms have long since been indifferent to the inhabitant of the spot. A bougie when for the first time passed into the urethra is painful to the patient;

*Pleasure and pain are always absolute sensations, but they may depend upon relative circumstances; that degree of cold, for example, does not incommode the inhabitant of Spitzbergen, which would be very painful to a man from a temperate climate. In order to understand how habit produces these effects, we must recollect that the repetition of the same sensations on the same part exhausts at length the sensibility of it. Hence we may conceive how the contact of a body upon a living surface may cease to be painful, while any division or solution of continuity of one of our organs will be always more or less so, because the nerves that are divided are unaccustomed to this sensation, and still possess their whole sensibility. The sense of sight furnishes us with a striking example of sensibility being exhausted by the continuation of the sensation; if we look for a long time with the same eye upon a white surface with a red spot in the middle of it, and then look upon a part that is all white, we shall perceive there a greenish spot; for the part of the retina which has been a long time in contact with the red rays, loses the peculiar sensibility that enables it to transmit this sensation perfectly; and of all the coloured rays which compose the white rays that now go to it, it transmits only those to which it is unacquainted; hence results the sensation of green.

eight days afterwards he is no longer sensible of it. Here we have comparative pain. Whatever destroys the texture of the organ is always productive of an absolute sensation; the simple contact of bodies at no time produces any other than a relative sensation.

Hence it is evident that the domain of absolute pleasure or pain, is much less extensive than that of these feelings when relative. The very words agreeable, or painful, imply a comparison made between the impression received by the senses, and the state of mind on which it is received. Now it is manifest that we could have referred only to relative pain and pleasure, as being submitted to the influence of habit. On these we shall occupy ourselves awhile.

And to shew that they are gradually worn away by habit as we have said, to the point of indifference, a variety of proofs may be adduced. Every foreign body in contact for the first time, with a mucous membrane, is creative of a disagreeable sensation, which by repetition, is diminished, and at last becomes altogether imperceptible. Pessaries in the vagina, tents in the rectum, the canula made use of for tying polypi of the nose, or the uterus, bougies, in the urethra, in the œsophagus, or trachea, styles and setons in the lachrymal passages, present us every day with these phenomena. The impressions of which the cutaneous organ is the seat, are all of them subjected to the same law. The sudden passage from cold to heat, or from heat to cold, is always the occasion of a disagreeable sensation, but such sensation gradually and at last entirely disappears, if the temperature of the atmosphere be within a certain range and constant. From hence proceed those various sensations, which we have from the change of climate, or season. Similar phenomena in the same way are the result of our successive perceptions of the dry or humid, the soft, or the hard qualities of bodies, and in general the same may be said of all our relative sensations, of what kind soever.

With respect to pleasure, we shall repeat what we have said of pain. The perfumer and the cook are by no means sensible in their several professions of those pungent enjoyments of which they are dispensers. In them the habit of perceiving has blunted the sentiment. The same is the case with all agreeable sensations whatever. Delightful views and delicious music are productive of a pleasure, the vivacity of which is soon lessened; for harmony and beauty if they for a long time continue to solicit our attention, are successively the sources of pleasure, of indifference, of satiety, nay even of disgust and aversion. This remark has been felt by all; Philosophers and Poets have all of them turned it to their account.

From whence arises this facility, which our sensations have of undergoing so many different, so many contrary modifications? To conceive it, let us first remark that the centre of these revolutions of pleasure, of pain, and of indifference, is by no means seated in the organs, which receive or transmit the sensation, but in the soul. The affections of the eye, of the tongue, and the ear, are at all times the same from the same objects, but to these affections at different times, we attach a variety of sentiments. In the second place we shall observe, that the action of the mind in each several sentiment of pain or pleasure, which has been the effect of a sensation, consists in a comparison between this sensation, and that by which it has been preceded, a comparison, which is not the result of reflection, but the involuntary effect of the first impression of the object. Now, the greater the difference between the actual and the past impression, the livelier will be the sentiment. The sensations which affect us the most, are those which we never before have experienced.

The consequence is, that in proportion as the same sensations are repeated, the less impression do they make upon us, because the comparison between the present and the past becomes less sensible. Pain then and pleasure naturally tend to their own annihilation. The art of prolonging our enjoyments, consists in varying their causes. Indeed were I to regard the laws of our material organization only, I might almost say, that constancy is but one of the happy dreams of the poet, and that the sex to which we at present bend, would possess but a very weak hold upon our attentions were their charms too uniform; I might almost assert that were every female cast in the same mould, such mould would be the tomb of love. But here let us forbear to insist upon the principles of physiology, where they tend to the destruction of those of morality. The one, and the other are equally solid, though sometimes at variance. We shall only notice, that at times the former unhappily are our only guides. It is then, that love disappears, with the pleasure which it has procured, and leaves us but disgust. It is then, that recollection too often carries us aside from our duties in rendering uniform that which we feel and that which we have felt, for such appears to be the essence of physical happiness, that past pleasure enfeebles the attraction of that which we enjoy.

The consequences are clear. Physical pleasure is nothing but a comparative sentiment; it ceases to exist when uniformity supervenes between the actual and past impression. By means of this uniformity habit must bring down pleasure to indifference: Such is the secret of the very great influence which it exercises over our enjoyments.

Such also is its mode of action on our pains. Time flies, it is said, and carries away sorrow; time is the true remedy of grief; and wherefore? The reason is, that the more sensations it accumulates upon that which has been painful, the more does it enfeeble the sentiment of comparison between what we are, and what we were. At last this sentiment becomes extinct. There are no eternal sorrows.

III. *Habit improves the judgment.*

I have just now proved that the sentiment is enfeebled by the effect of habit. It is as easy to demonstrate, that habit improves and enlarges the judgment.

When, for the first time, the eye wanders over an extensive country, or the ear is struck by a succession of harmonious proportions; when the taste, or the smell for the first time are affected by any very compound savour or scent, there arise from these sensations only confused and inexact ideas. We represent to ourselves the whole, its parts escape us. But let these sensations be repeated, and in proportion as they are so, will the judgment become precise and rigorous, and the knowledge of the object be perfected.

Let us for instance observe the man, who a stranger to theatrical amusement of every kind is introduced to the Opera. He will have but a very imperfect notion of it. The dancing, the music, the scenery, the actors, the splendor of the whole will be all confounded within his mind in a sort of delightful chaos. But let him be present at many representations, and whatever in this charming whole belongs to the several arts, will assume its separate place. He will have seized its detail, may form a judgment of it, and this he will do the more accurately in proportion to his opportunities of observation.

The above example affords us an abridgment of the picture of the man, who enjoys for the first time the spectacle of nature. The child, at its birth, is only capable of general impressions, but habitude, by gradually blunting these impressions, enables him to seize the particular attributes of bodies, and teaches him to see, to hear, to smell, to taste and to touch, by making him in each sensation descend successively from the confused notion of the whole to the precise idea of its parts. The animal life needs education, and this is one of its great characters.

Habit then while it hebetates our sentiments, improves our judgments of things. An example will render this truth indisputable. Most persons may recollect that in traversing a meadow, embellished with a variety of flowers, they have been sensible of a general fragrance only, the confused assemblage of all the particular odours which are exhaled from each individual flower; but in a short time from habit this first sentiment is weakened, it is soon afterwards altogether effaced. They then may have distinguished the odour of each particular plant, and formed a judgment at first impossible.

The two contrary operations thus of habit on our sentiments and judgments, tend as we see to one common end, the improvement, namely, of the animal life.

IV. *Of habit in the organic life.*

Let us at present compare the above-mentioned phenomena with those of the organic life, and the latter we shall see as constantly withdrawn from the influence of habit, as the former are subject to it.—Habit has never modified the circulation, or respiration, has never changed the mode of the processes of exhalation, absorption, or nutrition. A thousand causes would every day endanger our very existence, were these essential functions under the influence of habit.

The excretion of the urine and fecal matter may, nevertheless, be suspended, accelerated, and return according to laws determined by habit. The action of the stomach with respect to hunger, and its contact with certain aliments, appears also to be subordinate to habit; but here let us remark, that these different phenomena hold, as it were, a middle place between the two lives, are found on the limits of the one and the other, and participate almost as much of the animal as the organic life. In fact, they all of them take place on mucous membranes, a species of organ, which being at all times in relation with bodies foreign to our nature, is the seat of an inward tact, in every way analogous to the outward tact of the skin. The two must be necessarily subject to the same laws.—Can we be astonished at the influence of habit on both of them?

We cannot, and let us remark also, that the greater part of these phenomena, which begin as it were, and terminate the organic life, are connected with motions essentially voluntary, and in consequence, under the dominion of the animal life.

I shall not here enlarge on the numerous modifications of power, taste, and desire, which have their source in habit. I refer to the numerous works which have considered its influence in a different point of view from that which I have indicated.

CHAPTER VI.

GENERAL DIFFERENCES OF THE TWO LIVES WITH RESPECT TO MENTAL AFFECTION.

It is necessary to consider, under two relations, those acts, which little connected with the material organization of animals, are derived from this principle so little known in its nature, but so remarkable as to its effects, the centre of all their voluntary motions, and on the subject of which, there would have been less dispute, if philosophers, instead of attempting to reach its essence, had been contented with analyzing its operations. These actions, which we shall consider more especially in man, with whom they are the most perfect, are either purely intellectual, and relative to the understanding only; or they are the immediate product of the passions. Examined under the first point of view, they are the exclusive attribute of the animal, under the second of the organic life.

I. *Whatever relates to the understanding belongs to the animal life.*

It would be useless for me to insist on proving that meditation, reflection, the judgment, and all the operations of the mind depending upon an association of ideas are under the dominion of the animal life. We judge from impressions formerly or actually received, or from those which we ourselves create. Perception, memory, and the imagination are the principal bases, on which are founded the operations of the mind, but these very bases themselves repose upon the action of the senses.

Let us suppose a man at his birth to be deprived of all that exterior apparatus, which is destined to establish his connexions with surrounding objects; such man will not altogether be the statue of Condillac, because, as we shall see hereafter, other causes besides the sensations, may occasion within him the motions of the animal life; but at least will he not be able, a stranger as he is to every thing surrounding him, to form any judgment with respect to things. The intellectual functions with him will be null; volition, which is the consequence of these functions, will not have place, and consequently, that very extensive class of motions which has its immediate seat in the brain, and which itself is but an effect of the impressions made there, will in nowise belong to him.

It is by means of the animal life that man is so great, so superior to the beings, which surround him; by means of this that he possesses the sciences, the arts, and every thing which places him at a distance from the gross elements under which we represent brute matter; by this that he approaches spirituality; for industry and commerce, and whatever enlarges the narrow circle within which the efforts of other animals are confined, are exclusively under the dominion of the animal life of man.

The actual state of society then is nothing but a more regular development, a more marked perfection of the exercise of the different functions of this life; for one of its greatest characters as I shall hereafter prove, consists in its capability of being unfolded, while, in the organic life, there does not exist a part, which in the least degree may pass the limits which are set to it by nature. We live organically in as perfect, in as regular a way, when infants, as when men; but what is the animal life of the child compared with that of the man of thirty years of age?

We may conclude that the brain, the central organ of the animal life, is the centre of whatever relates to the understanding. I might here proceed to speak of its volume in man, and in animals, whose intelligence appears to decrease in proportion as the facial angle is diminished, and expatiate upon the different alterations of which the cerebral cavity is the seat, as well as on the disorders of the intellectual functions arising thence. But these things are all of them well enough understood. Let us pass to that order of phenomena, which though as foreign as the preceding to the ideas which we form of material appearances, are elsewhere seated.

II. *Whatever relates to the passions belongs to the organic life.*

My present object is not to consider the passions metaphysically. It little matters, whether they be all of them the modifications of a single passion, or dependent each of them upon a separate principle. We shall only remark, that many physicians in discussing their influence on the organic phenomena, have not sufficiently distinguished them from the sensations; the latter are the occasion of the passions, but differ from them widely.

It is true that anger, joy, and sorrow, would not affect us, were we not to find their causes in our connexions with external objects. It is true also, that the senses are the agents of these relations, that they communicate the causes of the passions, but in this they act as simple conductors only, and have nothing in common with the affections, which they produce; for sensation of every kind has its centre in the brain, sensation of every kind supposing impression and perception. If the action of the brain be suspended, sensation ceases; on the contrary, the brain is never affected by the passions; their seat is in the organs of the internal life.*

It is undoubtedly surprising that the passions, essentially as they enter into our relations with the beings which are placed about us, that modifying as they do at every moment these relations, that animating, enlarging, and exalting the phenomena of the animal life, which without them would be nothing but a cold series of intel-

* Bichat, in this paragraph, seems to say that the perceptions, which produce in us the passions, go directly and without the intervention of the brain, from the senses to the organs which he supposes to be affected by them. We cannot believe that such was his idea. The paragraph which follows must aid us in understanding it, and we shall endeavour to elucidate it by means of an example.

A certain event happens; a man is informed of it by means of his senses; he examines the event in itself, and its relations with antecedent and future events; his judgment weighs the various consequences of it, and shows them to be very disadvantageous to him. Here, as Bichat calls it, is a cold series of intellectual phenomena, which would take place in the individual, whoever the man may be who is affected by the event to which he has given his attention. It is found that the man who is injured is himself; then, from a knowledge of this only, his heart is sympathetically affected; its motions become more rapid and stronger, they send to the brain a greater quantity of blood, and this increase of habitual excitement in the organ of thought, produces a kind of mental attention in relation to the event that has taken place.

Thus, without the part that the heart has taken in it, this man would have seen with the most perfect indifference an event most disastrous to himself; for without even supposing anger, the least sentiment of sadness being a passion, we cannot believe that he is affected with it, if his liver, stomach or spleen are not at the moment in a particular state. But does not every thing on the contrary lead us to believe that anger exists before the agitation of the heart, and that this is the effect of it and not the cause? This agitation of the heart without doubt, by sending to the brain a greater quantity of blood than usual, contributes in its turn to develop and support the kind of alienation which accompanies anger; but it is necessary that the passion should already exist, since a favourable event, by producing as rapid motions of the heart, will produce nothing similar.

lectual movements; it is astonishing, I say, that the passions should neither have their end, nor beginning in the organs of this life, but on the contrary, that the parts which serve for the internal functions, should be constantly affected by them, and even occasion them according to the state in which they are found. Such notwithstanding is the result of the strictest observation.

I shall first observe, that the effect of every kind of passion is at all times to produce some change in the organic life. Anger accelerates the circulation of the blood, it multiplies the efforts of the heart. The passion of joy has not indeed so marked an influence upon the circulation, but alters it notwithstanding, and carries it lightly towards the skin. Terror acts inversely; this passion being characterized by a feebleness in the vascular system, a feebleness, which in hindering the blood from arriving at the capillary vessels, occasions the paleness which at such time is so particularly remarked. The effects of sadness and sorrow are nearly analagous.

So great indeed is the effect which the passions occasion upon the organs of the circulation, as even to arrest them altogether in their functions, where the affection is very powerful. In this way is syncope produced, for the primitive seat of syncope is always, as I shall soon prove it to be, in the heart, and not in the brain. In this the latter organ ceases to act, only because it ceases to receive the excitant necessary to its action. Hence also may happen death itself, the sometimes sudden effect of extreme emotion, whether such emotion as in anger so far exalts and exhausts the powers of the circulation, as not to leave them any further excitability, or whether as in the death occasioned by excessive grief, the powers at once excessively debilitated, are no longer capable of returning to their usual condition.

If the total and instantaneous cessation of the circulation be not occasioned by this debility, a variety of lesions in the blood vessels may be, notwithstanding, the effect of it. Desault has remarked that diseases of the heart, and aneurisms of the aorta, were augmented in number during the revolution, in proportion to the evils which it produced.

Nor does respiration depend less immediately upon the passions; that oppression, that anxiety, and sense of suffocation, which is the sudden effect of profound sorrow, must imply in the lungs a remarkable change and sudden alteratian. In that very long series of chronic or acute affections, the sad attribute of the pulmonary system, must we not often look to the passions to find the principle of the disease?

And that lively sensation at the pylorus under strong emotion, that ineffaceable impression which sometimes remains there, from whence succeed the schirri of which it is the seat, that sentiment of stricture, as it were, about the stomach, about the cordia in particular; under other circumstances those spasmodic vomitings, which sometimes follow the loss of a beloved object, the news of a fatal accident, or any kind of trouble, the cause of which are the passions; that sudden interruption of the digestive phenomena either in consequence of agreeable or disagreeable news, those affections of the bowels, those organic lesions of the intestines, of the spleen observed in cases of melancholy, or hypochondria, diseases which are always preceded by sad forebodings and the darker affections of the mind; do not all these indicate the very strict connexion of the digestive viscera with the state of the passions?

They do; and the secreting organs have not a less connexion with them. Sudden fear suspends the course of the bile, and is the occasion of jaundice; sudden anger is often the origin of bilious fever. In a state of sorrow or joy, sometimes even in that of admiration, our tears flow abundantly: the pancreas is not less frequently affected in hypochondria.

But the functions of the circulation, of digestion, respiration and secretion, are those which are most directly under the influence of the passions; those of exhalation, absorption and nutrition appear to be less so. Doubtless, the reason of this is, that these functions have not as the former any principal focus, or essential viscera, the state of which may be compared with that of the mind. Their phenomena disseminated throughout all the organs belong exclusively to none, and cannot be observed as well as those, the effects of which are confined within a narrow compass.

Nevertheless, the alterations, which these functions experience are not less real, do not become less apparent after a certain time; let the man, whose hours are marked by sorrow, be compared with him, who lives in peace of mind, and the difference of the process of nutrition in the one and in the other will easily be seen.

Let us, for a moment, approximate the times, when the terrible passions of sorrow, of fear and revenge seemed to brood over our country, and those, when safety and abundance continually supplied us with the gayer ones so natural to us; we may then recall what at the two periods were the outward appearances of our countrymen, and appreciate the influence of the passions on the process of nutrition. The very expressions which are continually in our mouths that such a one is dried up with envy, preyed upon by remorse, consumed and wasted away with sorrow, do not even these announce how much the nutritive functions are modified by the passions?

I know not for what reason the powers of absorption and exhalation should not be subject to the same influence, though they appear to be less so; may not dropsies, and all infiltrations of the cellular membrane, the peculiar vices of these two functions, depend on mental affection?

In the midst of these disturbances, of these partial or general revolutions which are produced by the passions in the organic phenomena, let us consider the actions of the animal life; they constantly remain unaltered, or if they do experience any derangement, such derangement has ever its source in the internal functions.

From so many considerations we may conclude that it is upon the organic and not upon the animal life that the passions exercise their influence. Accordingly, whatever serves to paint them must relate to the former. Of this assertion, our gestures which are the mute expressions both of the sentiment and understanding are a remarkable proof. Thus if we indicate any operation of the memory, imagination or judgment, the hand is carried to the head; do we wish to express either love or hatred, or joy or sorrow, it is to the seat of the heart, the stomach or intestines, that it is then directed.

The actor, who should mistake in this respect, who in speaking of sorrow should refer his gestures to his head, or carry them to his heart, for the purpose of announcing an effort of genius, would be ridiculed for a reason which we should better feel than comprehend.

The very language of the vulgar, at a time when the learned referred to the brain, as the seat of the soul, affections of all kinds, distinguished the respective attributes of the two lives. We have always said a strong head, a head well organized to denote perfection of mind; a good heart, a sensible heart, to indicate proper feeling. The expressions of fury circulating in the veins, and stirring up the bile; of joy making the heart leap, of jealousy distilling its passions into the heart, are by no means poetical expressions, but the enunciation of that which actually takes place in nature. In this way do all these expressions, the language of the internal functions enter into our poetry, which in consequence is the language of the passions or the organic life, as ordinary speech, is that of the understanding or the animal life. Declamation holds a middle place between the two, and animates the cold language of the brain by the expressive language of the inward organs.

I shall even venture to assert that anger and love inoculate, if I may so express myself, into the humours, into the saliva particularly, a radical vice, which renders dangerous the bite of animals at such times; for these passions do really distil into the fluids a poison, as we indicate the fact by our common expressions. The violent passions of the nurse have frequently given her milk a pernicious quality, from whence disease has followed to the child; and in the same way shall we explain from the modifications which the blood of the mother receives under strong emotion, the manner, in which these emotions operate on the nutrition, the conformation, and even on the life of the fœtus. And not only do the passions essentially influence the organic functions, in affecting their respective viscera, but the state of these viscera, their lesions, the variation of their forces concur in a decided way to the production of the passions themselves. Their relations with age and temperament, establish incontestably this fact.

Who does not know for instance, that the individual of the sanguine temperament, whose expansion of lungs is great, whose circulatory system is large and strong; who does not know that such a man is possessed of a disposition to anger and violence? that when the bilious system prevails, the passions of envy and hatred are more particularly developed? that when the lymphatic system is pronounced, are pronounced also the inactivity and dulness of the individual?

In general that which characterises any particular temperament, consists in a correspondent modification on one hand of the passions, and on the other of the state of the organic viscera. The animal life is almost always a stranger to the attributes of the temperaments.

The same may be said of age; the weakness of the organization of the child coincides with his timidity. The development of the pulmonary and vascular system, with the courage and temerity of the youth; that of the liver, and the gastric system with the envy, ambition and intrigue of manhood.

In considering the passions as affected by climate and season, the same relations are observed between them and the organic functions; but physicians have sufficiently noticed these analogies, and it would be useless to repeat them.

At present, if from man in a state of health, we look to man in a state of disease, we shall see that the lesions of the liver, of the stomach, of the spleen, the intestines and heart produce a variety of alterations in our affections, which all of them cease together with their causes.

The ancients, better than our modern mechanicians, then were acquainted with the laws of the economy, in supposing that our bad affections were evacuated by purgatives, together with the noxious humours of the body. By disembarrassing the primæ viæ they got rid of these affections. In fact how dark a tint does the fulness of the gastric viscera cast upon the countenance! the errors of the first physicians on the subject of the atrabilis, were a proof of the precision of their observations on the connexion of these organs with the state of the mind.

In this way every thing tends to prove, that the organic life, is the term, in which the passions end, and the centre from whence they originate. But we shall be asked perhaps, why vegetables, which live organically, do not offer any vestige of them? the reason seems to be, that besides their want of the natural excitants of the passions, namely the external apparatus of the senses, they are wanting also in those internal organs, which concur most especially to their production, such as the digestive system, that of the general circulation, and that of the great secretions, which are remarked in animals.

Such are the reasons also why the passions are so obscure in the Zoophytes, in worms, &c. and why in proportion as the organic life becomes more simple in the series of animals, and loses its important viscera, the passions are less observable.

III. *The passions modify the actions of the animal life though seated in the organic life.*

Although the passions are the especial attributes of the organic life, they nevertheless exert an influence over the animal life, which it is necessary to examine. The muscles of volition are frequently brought into play, and their actions sometimes exalted, sometimes lowered by them; the strength for instance of the man in anger is doubled, and tripled; is exercised with an energy, of which he is not himself the master. The source of this augmented power is manifestly in the heart.

This organ, as I shall prove hereafter, is the natural excitant of the brain, by means of the blood, which it sends thither. The energy of the cerebral action is in proportion to the energy of the stimulus applied to it, and we have seen that the effect of anger is to impress a great vivacity upon the circulation; hence, a larger quantity of blood than usual is thrown upon the brain in a given time. The consequence is an effect analogous to that which happens in the paroxysm of ardent fever, or the immoderate use of wine.

It is then, that the brain being excited strongly, excites as strongly the muscles which are submitted to its influence; accordingly their motions must be involuntary, for the will is a stranger to those spasms, which are determined by a cause which irritates the medullary organ. Such cause may be a splinter of bone, blood, pus, the handle of a scalpel as in our experiments; in short of various kinds.

The analogy is exact, the blood being transmitted to the brain in greater quantity than usual, produces upon it the effect of the different excitants above mentioned. In these different motions then, the brain is passive; it engenders indeed at all times the necessary irradiations for producing such motions, but these irradiations in the present instance are not the effect of the will.

It may be observed also, that under the influence of anger, a constant relation exists between the contractions of the heart and the locomotive organs; they both increase at the same time, and at the same time resume their equilibrium. In every other case on the contrary there is no appearance of this relation; the action of the heart is uniformly the same, whatever the affection of the muscular system. In convulsion and palsy, the circulation is neither impeded nor accelerated.

In the passion of anger, in fact, we see the very mode of the influence, which the organic life exercises over the animal life. In the passion of fear also, where on the one hand the enfeebled heart directs a less quantity of blood, and consequently a smaller cause of excitement to the brain, and where on the other hand a debility may be observed in the external muscles, we may perceive the connexion of cause and effect. This passion offers in the first degree the phenomenon, which in the last degree is shewn by those lively emotions, which suspending altogether the efforts of the heart, occasion a sudden cessation of the animal life and syncope.

But in what way shall we account for those modifications of the motions of the animal life, which are the effect of the passions? In what way shall we explain the cause of those infinite varieties, which succeed each other in the moveable picture of the face?

All the muscles which are the agents of these motions receive their nerves from the brain and lie under the influence of the will. What is the reason then, that when acted on by the passions, they cease to do so, and enter under the class of those motions of the organic life, which are put forth without our direction or consciousness. The following if I mistake not is the best explanation of the fact.

The most numerous sympathies exist between the internal viscera, and the brain or its different parts. Every step which we make in practice presents us with affections of the brain originating sympathetically from those of the liver, stomach and intestines. Now as the effect of every kind of passion is to produce a change of power in one or the other of these viscera, such change will sympathetically excite either the whole of the brain or some of its parts, whose re-action upon the muscles, which receive from thence their nerves, will produce the motions, which are then observed. In the production of these motions the cerebral organ accordingly must be passive, it is active only when the will presides over its efforts.

The effects indeed of the passions are similar to those diseases of the internal organs, which by sympathy are the causes of atony, palsy, and spasm.

But perhaps the inward organs act upon the voluntary muscles, not by means of the immediate excitement of the brain, but by direct nervous communication. Of what importance to us is the manner? We are not at present occupied on the so much agitated question of the manner of sympathetic communication.

The essential thing is the fact itself. Now in this fact, there are two things evident; the affection of an internal organ by the passions, and secondly a motion produced in consequence of such affection in muscles, on which this organ in the common series of the phenomena of the two lives has no kind of influence. This is surely a sympathy, for between it, and those with which convulsion, or spasm of the face present us, when occasioned by any lesion of the phrenic centre, or the stomach, the difference is only in the cause, which affects the internal organ.

Any irritation of the uvula, or the pharynx convulsively agitates the diaphragm. The too frequently repeated use of fermented liquors occasions a general trembling of the body. But that which happens in one mode of gastric affection, may happen in another. What matters it, whether the stomach or liver be irritated by passion or by some material cause? It is from the affection, and not from the cause of the affection that results the sympathy.

Such in general is the manner in which the passions withdraw from the empire of the will, those motions which by nature are voluntary. Such is the manner in which they appropriate to themselves, if I may so express myself, the phenomena of the animal life, though they possess their seat essentially in the organic life.

When very strong, the very lively affection of the internal organs produces so impetuously the sympathetic motions of the muscles, that the action of the brain is absolutely null upon them; but the first impression past, the ordinary mode of locomotion returns.

A man is informed by letter and in presence of company, of a piece of news, which it is his interest to conceal. All on a sudden his brows become contracted, he grows pale, and his features are moulded according to the nature of the passion, which has been excited. These are sympathetic phenomena produced by the abdominal viscera which have been affected by the passions, and which in consequence belong to the organic life. But in a short time the man is capable of putting a constraint upon himself, his countenance clears up, his colour returns. Meanwhile the interior sentiment continues to subsist however, but the voluntary have overpowered the sympathetic motions, the action of the brain has surmounted that of the stomach or the liver; the animal life of the man has resumed its empire.

In almost all the passions the movements of the animal life are mingled with those of the organic life, or succeed to them; in almost all the passions, the muscular action is in part directed by the brain, in part by the organic viscera. The two centres alternately overpowered the one by the other, or remaining in a state of equilibrium, constitute by the modifications of their influence, those numerous varieties which are seen in our mental affections.

And not only on the brain, but on all the other parts of the body also do the viscera affected by the passions exercise their sympathetic influence. Fear affects the stomach in the first place, as is proved by the sense of stricture felt there at such time.* But when thus affected, the organ re-acts upon the skin, with which it has so strict a connexion, and the skin immediately becomes the seat of the cold and sudden sweat, which is then so often felt. This sweat is still however of the same nature with that which is occasioned by tea, or warm liquids. Thus a glass of cold water, or a current of cold air, will suppress this excretion by means of the relation, which exists between the skin, and the mucous surfaces of the stomach or bronchiæ. We must carefully distinguish between sympathetic sweating, and that, of which the cause is directly made upon the skin.

Hence though the brain be not the only term of the re-action of the internal viscera which are affected by the passions, it is nevertheless the principal one, and in this respect may always be considered as a focus at all times in opposition to that which is centered in the internal organs.

IV. *Of the epigastric centre.—It does not exist in the sense, which Authors have pretended.*

Authors have never been at variance with respect to the cerebral focus. The voluntary motions have ever

* There is no proof that the sense of stricture which is felt in the epigastric region, is connected with the stomach; and if it were proved that it was so, it would not follow from it that this organ was primarily affected from fear. The same passion sometimes acts differently in different individuals; there are some who do not feel this stricture in the epigastric region, but who are deprived of the use of their legs; must it be said that in these individuals the seat of fear is in the extensor muscles of the legs? If the introduction of a warm drink into the stomach produces an increase of cutaneous exhalation, should we conclude from analogy, that it is by acting primarily upon this organ that fear causes that cold sweat which sometimes accompanies it?

been regarded as an effect of its irradiations. They do not equally agree upon the subject of the epigastric focus; some of them place it in the diaphragm, others in the pylorus, others in the plexus of the great sympathetic nerve.*

* *Note by the Author.*—This nervous network, going principally from the semi-lunar ganglion, belongs to almost the whole abdominal vascular system, whose various ramifications it follows. It is, according to the usual manner of considering it, one of the divisions of the great sympathetic; but it seems to me that the ideas of anatomists respecting this important nerve are not conformable to nature.

Every one considers it as a medullary cord, extending from the head to the sacrum, sending in its course various ramifications to the neck, the thorax and the abdomen, following in its distributions a course analogous to those nerves of the spine, and deriving its origin from those nerves, according to some, and from those of the brain, according to others. Whatever be the name by which it is designated, sympathetic, intercostal, &c.; the manner of describing it is always the same.

I believe that this manner is altogether wrong, that there really exists no nerve analogous to the one designated by these words, and that what is taken for a nerve is only a series of communications between different nervous centres, placed at different distances from each other.

These nervous centres are the ganglions, scattered throughout the different regions, they have all an independent and insulated action. Each is a particular centre which sends in various directions many ramifications, which carry to their respective organs the irradiations of the centre from which they go off. Among these ramifications, some go from one ganglion to another; and as these branches which unite the ganglions form by their union a kind of continuous cord, this has been considered as a distinct nerve; but these branches are only communications, simple anastomoses, and not a nerve analogous to the others.

This is so true, that these communications are often interrupted. There are subjects, for example, in whom is found a very distinct interval between the pectoral and lumbar portions of what is called the great sympathetic, which seems to be cut off in this place. I have seen this pretended nerve cease and afterwards reappear, either in the lumbar or sacral region. Who does not know that sometimes a single branch, sometimes many go from one ganglion to another, especially between the last cervical and the first dorsal; that the size of these branches

But on this point, they appear to me to be all of them in the wrong. They assimilate or rather identify the second with the first focus—they think, that the passions, as well as the sensations have their seat in an invariable

varies remarkably; and that after having furnished many divisions, the sympathetic is larger than before it gave off any?

These considerations evidently prove that the communicating branches of the ganglions no more suppose a continuous nerve than the branches which go from each of the cervical, lumbar or sacral pair to the two pair which are superior and inferior to them. In fact, notwithstanding these communications, we consider each pair in a separate manner, and do not regard their union as a nerve.

It is necessary to describe in the same way separately each ganglion, and the branches which go off from it.

Hence I shall divide hereafter in my descriptions, in which I have hitherto pursued the ordinary course, the nerves into two great systems, one arising from the brain, and the other from the ganglions; the first has a single centre, the second has a great number of them.

I shall first examine the divisions of the cerebral system; I shall afterwards treat of the system of the ganglions, which may be subdivided into those of the head, the neck, the thorax, the abdomen and the pelvis.

In the head is found the lenticular ganglion, that of Meckel, that of the sublingual gland, &c. &c. Though no communication connects these different centres, either together or with the pretended great sympathetic, yet their description belongs to that of the nerves of which this is the connecting link, as the communications are arrangements merely accidental to this system of nerves.

In the neck there are the three cervical ganglions, sometimes another upon the side of the trachea, in the thorax the twelve thoracic, in the abdomen the semi-lunar, the lumbar, &c. and in the pelvis the sacral; these are the different centres whose ramifications it is necessary to examine separately, as we do those of the cerebral centre.

For example, I shall first describe the semi-lunar ganglion, as we do the brain; then I shall examine the branches, among which, is that by which it communicates with the thoracic ganglions, that is to say, the great splanchnic; for it is very incorrect to consider this nerve as giving origin to the ganglion. In the same way, in the neck and the head, each ganglion will be first described; then I shall treat of its branches, among which are those of communications. The arrangecentre. That, which has led them to this opinion has been the sentiment of oppression, which is felt at the cardia under all painful affection.

But it is to be remarked, that in the internal organs, the sentiment produced by the affection of a part is always an unfaithful index of the seat and extent of such affection.

ment being nearly the same for the ganglions of the thorax, the pelvis and the loins, the description of each region will be similar.

This manner of describing the nerves, by placing an evident line of demarcation between the two systems, exhibits these two systems such as they really are in nature.

What anatomist, in fact, has not been struck with the differences that exist between the nerves of these two systems? Those of the brain are larger, less numerous, whiter, more compact in their texture and exhibit less variety. On the contrary, the extreme tenuity, great number, especially towards the plexuses, greyish colour, remarkable softness of texture and varieties extremely common are characters of the nerves coming from the ganglions, if we except those of communication with the cerebral nerves and some of those which unite together these small nervous centres.

Besides, this division of the general system of the nerves into two secondary ones, accords very well with that of life. We know in fact that the external functions, the sensations, locomotion and the voice are all dependent on the cerebral nervous system; that on the contrary, most of the organs which perform the internal functions derive from the ganglions their nerves, and with them the principle of their action. We know that animal sensibility and contractility arise from the first, and that where the second alone are found, there is only organic sensibility and contractility.

I have said that the termination of this kind of sensibility and the origin of the corresponding contractility are in the organ in which they are noticed; but perhaps both the termination and origin are more remote, and are in the ganglion from which the organ receives its nerves, as the termination of animal sensibility and the origin of the contractility of the same species are always in the brain. If it be so, as the ganglions are very numerous, we can understand why the forces of organic life do not refer, like those of animal life, to a common centre.

It is evident from these considerations, that there is no great sympathetic nerve, and that what has been designated by this word is only an

For example, hunger must undoubtedly affect the whole of the stomach, but the sensation of hunger is transmitted to us only by the cardia. A large inflamed surface in the pleura for the most part gives rise to a pain, which is felt only in a point. How often does it happen that in the head or the abdomen a pain which is referred but to a very limited space coincides with a largely disseminated affection, with an affection possessing even a different seat from that which is presumed. We should never consider the place to which we refer the sentiment as a sure index of that which the affection occupies, but only as a sign that it exists either there or thereabouts.

From all this it follows, that to form a judgment of the organ, to which such or such a passion relates, we ought to recur to the effect produced in the functions of the organ by the influence of the passion, and not to the feelings of the patient. In setting out from this principle it will be easy to see, that it is sometimes the stomach and alimentary canal, sometimes the sanguiferous system, sometimes the viscera belonging to the secretions which experience a change.

assemblage of small nervous systems, with distinct functions, but with communicating branches.

We see then what should be thought of the disputes of anatomists respecting the origin of this pretended nerve, placed in the fifth, sixth pair, &c. in those of the neck, back, &c.

Many physiologists have entertained concerning the ganglions opinions similar to those which I have now offered, by considering these bodies as small brains; but it is essential that these opinions should enter into the description, which, as it is now made, gives a very inaccurate idea both of these nervous centres and of the nerves which go off from them.

The expression of *nervous branches giving origin to such or such a ganglion*, &c. resembles that in which we should consider the brain as arising from the nerves of which it is itself the origin.

I shall not repeat the proofs of this assertion, but supposing it to be demonstrated, I shall assert that there does not exist for the passions as there does for the sensations a fixed and constant centre; that on the contrary the liver, the lungs, the spleen, the stomach, and the heart, are turn by turn affected, and at such time form that epigastric centre so celebrated in modern works; and if in general we refer to this region the sensible impression of all our affections, the reason is that all the important viscera of the organic life, are there concentrated. In fact, if nature had separated these viscera, had the liver for instance been placed in the pelvis, and the stomach in the neck, the heart and spleen remaining as they now are seated, in such case the epigastric focus would disappear, and the local sentiment of our passions vary according to the part affected.

In determining the facial angle, Camper has thrown much light upon the proportion of intelligence enjoyed by the several classes of animals. It appears that not only the functions of the brain, but that all those of the animal life which are centred there, have this angle for the measure of their perfection.

It would be a very pleasing thing could we indicate in the same way a measure, which assumed from the organs of the internal life, might fix the rank of each species with regard to the passions. The dog is much more susceptible than other animals of the sentiments of gratitude, of joy, of sorrow, of hatred, and of friendship; has he any thing more perfect in his organic life? the monkey astonishes us by his industry, his disposition to imitate, and by his intelligence; his animal life is certainly superior to that of every other species. Other animals, such as the elephant, interest us by their attachment, their affection, their passions; they delight us also with their address, and the extent of their intelligence. With them the cerebral centre and the organic viscera are perfect alike.

A rapid glance over the series of animals will show us also, that in some of them the phenomena, which arise from sensation predominate over those which have their origin in the passions; in others we shall see the latter superior in power to the former, and in others again, a balance established between the two. These circumstances, which we remark in the long chain of animated beings, we may remark in the human species when considered individually In one man the passions are the great principle of motion; the influence of his animal life is continually surpassed by that of his organic life, and incessantly induces him to act in a way to which the will is almost a stranger, and which often entails upon him the bitterest regret, when his animal life resumes its empire. In another man, the animal life is the stronger of the two. In such case, the understanding seems to be augmented at the expense of the passions, the latter remaining in that silence, to which the organization of the individual has condemned them.

That man enjoys the happiest constitution in whom the two lives are balanced, in whom the cerebral and epigastric centres exercise the one upon the other an equal action, whose intellect is warmed, exalted, and animated by the passions, but whose judgment makes him at all times master of their influence.

It is this influence of the passions over the actions of the animal life, which composes what is named the character. Character as well as Temperament depends upon the organic life; possesses all its attributes, and is a stranger to the will in all its emanations; for our exterior actions form a picture of which the ground and design do indeed belong to the animal life, but upon which the organic life extends the shading and colouring of the passions. The character of the individual is constituted by such shades and colours.

The alternate predominance of the two lives has been remarked by almost all philosophers. Plato, Marcus Aurelius, Bacon, St. Augustine, St. Paul, Leibnitz, Van Helmont, Buffon and many others have recognized in man two principles, by one of which we become the masters of all our moral actions, by the other the contrary. We have nothing to do with the nature of these principles. Our business is with their phenomena; we shall analyze the relations by which they are united.

CHAPTER VII.

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GENERAL DIFFERENCES OF THE TWO LIVES WITH RESPECT TO VITAL POWER.

The greater number of Physicians, who have written upon the vital properties, have begun by researches on their principle, have endeavoured to descend from the knowledge of the nature of this principle to that of its phenomena, instead of ascending from observation to theory. The Archæus of Van Helmont, the soul of Stahl, the vital principle of Barthez, the vital power of others, have each in their turn been considered as the sole centre of every action possessing the character of vitality, have each in their turn been made the common base of every physiological explanation. But these bases have every one of them been sapped, and in the midst of their wrecks have remained the facts alone which rigorous experiment has furnished upon the subject of sensibility and motility.

So narrow indeed are the limits of the human understanding, that the knowledge of first causes has almost always been interdicted. The veil, which covers them envelops with its innumerable folds whoever attempts to rend it.

In the study of nature, principles are certain general results of first causes, from whence proceed innumerable secondary results. The art of finding the connexion of the first with the second is that of every judicious mind. To seek the connexion of first causes with their general effects is to walk blindfold in a road from whence a thousand paths diverge.

Of what importance besides to us are these causes? Is it necessary to know the nature of light, of oxygen and caloric to study their phenomena? Without the knowledge of the principle of life, cannot we analyze its properties? In the study of animals let us proceed as modern metaphysicians have done in that of the understanding. Let us suppose causes, and attach ourselves to their general results.

I. *Difference between vital power and physical law.*

In considering the powers of life, we shall perceive in the first place a remarkable difference between them and the laws of physics. The first incessantly vary in their intensity, in their energy, in their development, are continually passing from the last degree of prostration, to the highest pitch of exaltation, and assume under the influence of the most trifling causes a thousand modifications; for the animal is influenced by every thing which surrounds him; he wakes, he sleeps, reposes or exercises himself, digests, or is hungry, is subject to his own passions, and to the action of foreign bodies. On the contrary the physical laws are invariable, the same at all times, and the source of a series of phenomena at all times similar. Attraction is a physical power; it is always in proportion to the mass of brute matter in which it is observed; sensibility is a vital power; but in the same mass of matter, in the same organic part its quantity is perpetually changing.

The invariability of the laws which preside over the phenomena of physics, enables us to apply the formula of calculation to all the sciences, which have them for their object. Applied to the actions of the living body, the mathematics can never give us formula. The return of a comet, the resistance of a fluid in traversing an inert canal, the rapidity of a projectile may be calculated; but to calculate with Borelli the force of a muscle, with Keil the velocity of the blood, with Jurine and Lavoisier the quantity of air, which enters into the lungs, is to build upon a quicksand, an edifice solid of itself, but necessarily decreed to fall for want of a foundation.

This instability of the vital powers, this disposition, which they continually have to change, impress upon all the physiological phenomena a character of irregularity which particularly distinguishes them from those of physics. The latter forever the same, are well known when once they have been analyzed; but who can say that he knows the former, because he has analyzed them under the same circumstances, a multitude of times. The urine indeed, the saliva, or the bile indifferently taken from such or such a subject, may be analyzed, and hence results our animal chemistry; but such a chemistry is the dead anatomy of the fluids, not a physiological chemistry. The physiology of the fluids should be composed of the innumerable variations which they experience according to the different states of their respective organs.

The urine after taking food is not the fluid, which it is after sleeping; it contains in winter, principles which are foreign to it, during summer, when the principal excretions are made by the skin. The simple passage from heat to cold, in suppressing sweat, and the pulmonary exhalation, will change its composition. The same is true of the other fluids; the state of the vital powers in the organs, which are the sources of them, changes at every moment; and therefore, the secreted substances, which entirely depend upon the mode of action in the organs, must be as various.

Who will venture to assert, that he knows the nature of a fluid of the living economy if he has not analyzed it in the infant, in the adult, and the aged, in the male and in the female, at every season, during the calm of the mind, and the storm of the passions, which so manifestly influence its nature? To know such fluid perfectly, will it not be requisite also to examine the different alterations of which it is succeptible in consequence of disease?

The instability of the vital powers, is the quicksand on which have sunk the calculations of all the Physicians of the last hundred years. The habitual variations of the living fluids, dependent on this instability, one would think should be no less an obstacle to the analyzes of the chemical physicians of the present age.

From this reasoning it is easy to perceive, that the science of organized bodies should be treated in a very different manner from that of inorganic bodies. To the former a different language almost is requisite; for the greater number of the words, which we transfer from the physical sciences, into those of the animal or vegetable economy, incessantly recall ideas, which are by no means consistent with their phenomena.

Had physiology been cultivated by men before physics, I am persuaded that many applications of the former would have been made to the latter; rivers would have been seen to flow from the tonic action of their banks, crystals to unite from the excitement, which they exercise upon their reciprocal sensibilities, and planets to move because they mutually irritate each other at vast distances. All this would appear unreasonable to us, who think of gravitation only in the consideration of these phenomena; and why should we not in fact be as ridiculous when we come with this same gravitation, with our affinities and chemical compositions, and with a language established upon their fundamental data to treat of a science, with which they have nothing whatsoever to do. Physiology would have made a much greater progress, if all those who studied it, had set aside the notions which are borrowed from the accessary sciences, as they are termed. But these sciences are not accessary; they are wholly strangers to physiology, and should be banished from it wholly.*

* Bichat often complains in his works of the injury that has been done to the physiological sciences, by the attempts that are made to facilitate the study of them by means of physics. He was not competent to decide the question, not having sufficient data in the sciences, the use of which he reprobated; the most that he should have said, was that a bad application had been made of them. Even this reproach was too general to be just. No doubt, mankind have been led into errors by attempting to support on slight foundations a science which was still in its infancy; but even in the time of Bichat it could not be denied that it was to the progress of these same sciences, that was owing the explanation of many very important phenomena; that by it was ascertained what takes place in respiration, and by what means a living body always supports itself between certain limits of temperature, &c.

Physics and chemistry are related to each other in many points, because the same laws in a variety of instances preside over the phenomena of both of them; but an immense interval divides them from the science of organic bodies; because a very great difference exists between the laws which are proper to them, and those of life. To say that physiology is made up of the physics of animals, is to give a very inaccurate idea of it; as well might we say that astronomy is the physiology of the stars.

But the present digression has already been much too long. We shall now consider the vital powers with respect to the two lives of the animal.

II. *Difference between the vital properties and those of texture.*

In examining the properties of every living organ, we may distinguish them into two kinds. Those of one kind are dependent immediately upon life, begin and finish with it, or rather form its principle and its essence. Those of the other are connected with it only indirectly, and appear rather to depend upon the organization and texture of the parts of the body.

The faculties of perceiving and spontaneously contracting are vital properties: extensibility, and the faculty of contraction upon the cessation of the extending power, are properties of texture; the latter it is true, are possessed of a greater energy when existing in the living fibre, but they remain with the organ when life has ceased; the decomposition of the organs, is the term of their existence. I shall first examine the vital properties.

III. *Of the two kinds of sensibility ; of the animal and organic sensibilities.*

It is easy to perceive, that the vital properties can be only those of perception and motion, but in the two lives they possess a very different character. In the organic life, sensibility is the faculty of receiving an impression; in the animal life, it is the faculty of receiving an impression and moreover of referring such impression to a common centre.* The stomach is sensible to the presence of aliments, the heart to the stimulus of the blood, the excreting tube to the contact of the fluid, which is peculiar to it; but the term of this sensibility is in the organ itself. In the same way do the eyes, the membranes of the nose and the mouth, the skin, and all the mucous surfaces, at their origin, receive an impression from the bodies which are in contact with them, but they afterwards transmit such impression to the brain, which is the general centre of the sensibility of these organs.

There is an animal sensibility then, and an organic sensibility. Upon the one depend the phenomena of digestion, circulation, secretion, exhalation, absorption,

* It must be remembered that the existence of such a sensibility is purely conjectural. As it is not transmitted to a common centre, we can recognize it only by its effects. In order to explain these effects, there is no need of admitting a similar faculty. This sensibility moreover, if its existence should be admitted, would be found continually in fault. The stomach, for example, allows a substance to go out of its cavity which could never serve for aliment, provided this substance exhibits a degree of fluidity approaching that of chymè. The absorbents take up the most noxious fluids, those even the action of which is sufficiently powerful to destroy the organization of their parietes; the heart contracts without the entrance of the blood into it, &c.

and nutrition. It is common to the plant, and the animal; the Zoophyte enjoys it as perfectly as the most perfectly organized quadruped. On the other depend sensation and perception, as well as the pain and pleasure which modify them. The perfection of animals, if I may so speak, is in proportion to the quantity of this sensibility, which has been bestowed upon them. This species of sensibility is not the attribute of vegetable life.

The difference of these two kinds of sensitive power is particularly well marked in the manner of their termination, in the case of violent and sudden death. In such case, the animal sensibility is at once extinguished; there can no longer be found any trace of it at the moment which succeeds to strong concussion of the brain, to great hæmorrhage or asphyxia; but the organic sensibility survives such accidents more or less. The lymphatics continue to absorb, the muscle is still sensible to stimuli, the nails and the hair continue to be nourished, and in consequence are sensible of the fluids which they imbibe.*

* This is altogether inaccurate; a nail in growing is not nourished, any more than the mucus is nourished in the nasal fossæ, or the urine in the bladder. The nails, the hair on the various parts of the body and the hair of the head, all in a word epidermoid productions, are the result of real secretions which do not differ from the secretions of which we have just spoken, only in this, that the product instead of remaining fluid like the urine, or viscid like the mucus, hardens as it comes out of the secretory organ, like the thread of the silk worm, or that of the spider. A certain number of these organs is commonly arranged in such a manner, that the matter secreted by each of them is found in a fluid state in contact with that of the neighbouring organs, with which it is agglomerated in hardening. Arranged in concentric circles around a small cone, they produce a hollow cylinder; extended in parallel lines upon a broad surface, they produce a flattened lamina. Such is the manner in which the nails and the hair are formed. We see from this that the epidermoid productions grow, but are not nourished. The hair exhibits, it is true, an internal cavity, filled with a coloured fluid,

It is often a considerable time before all traces of this sensibility are effaced; the annihilation of the other is instantaneous.

Though at the first glance, the two sensibilities present us so remarkable a difference, their nature nevertheless appears to be essentially the same. The one perhaps is only the maximum of the other, is the same force, but according to its intensity is shown under different characters. Of this the following observations are proofs.

There are different parts in the economy, where these faculties are concatenated, and succeed each other insensibly. The origin of all the mucous membranes is an example of such parts. We have the sensation of the passage of aliments in the mouth, and the back part of it; this sensation becomes weaker at the beginning of the œsophagus, decreases still towards its middle, and disappears at its end, as well as in the stomach, where the organic sensibility only remains. The same phenomena may be observed in the urethra, &c. In the neighbourhood of the skin, the animal sensibility exists; it gradually diminishes, however, and becomes organic in the interior of the system.

Divers excitants applied to the same organ may alternately produce the one, and the other mode of sensibility. When irritated by acids, by very concentrated alkalies, or by a cutting instrument, the ligaments do not transmit to the brain the very strong impression which is made upon them, but if they be twisted, distended or rent, a

which appears to be necessary for its preservation; but we can easily conceive how an oily fluid may help to preserve it, by giving it suppleness and thus preventing it from breaking. This fluid is poured into the canal in which it is found, and it is not the hair which draws it in, any more at least, than a capillary tube draws in the fluid into which its extremity is plunged.

lively sensation of pain is the result.* I have established this fact by a number of experiments in my treatise on the membranes. The following is another of the same kind, which I have since observed. The parietes of the arteries as we know are sensible to the blood by which they are traversed, but at the same time are the term of this sentiment. If a fluid, however, which is foreign to this system, be injected into it, the animal will immediately discover by his cries, that he is sensible of the presence of such fluid.†

We have seen that it is a property of habit, to weaken the sentiment, to transform into indifferent sensations all those of pleasure, or of pain. Foreign bodies, for example, will make upon the mucous membranes a painful impression during the first days of their application to it; they develop in such parts the animal sensibility, but by little and little this sensibility decreases, and the organic alone subsists. In this way the urethra is sensible of the bougie

* The idea of endowing each texture with a peculiar kind of sensibility in relation with its uses is one which pleases the imagination. The ligaments are designed to oppose the separation of the bones; they should remain insensible to every kind of stimulus that does not tend to disunite these parts, and pain consequently, should not be produced but from distension or twisting. Unfortunately this supposition is not well founded, the facts on which it rests were not accurately observed. It is very true that in twisting these ligaments, the animal almost always cries out, but it is because we at the same time stretch some neighbouring parts endowed with sensibility. When this is prevented and the experiment is made with proper precaution, we can twist, distend or tear the ligament, without appearing to give the animal any pain.

† So, as long as the fluid is retained in the artery, which is easily done by means of ligatures, no pain is manifested; but when the irritating substance is carried by the vessels to the heart or to any other sensible part, we can easily conceive that the animal must experience pain, for the irritant always produces its effect, whether it be carried directly to the part or arrive there by means of the circulation.

as long as it continues there, for during the whole of such time, the action of the mucous glands of the passage is augmented, from whence arises a species of catarrh, but the individual for the first moments only had a painful consciousness of the presence of the instrument.

We every day observe, that inflammation in exalting the organic sensibility of a part, transforms the organic into the animal sensibility: the cartilages thus, and the serous membranes which in their ordinary state have only the obscure sentiment, which is necessary to their nutrition, in an inflammatory state are possessed of an animal sensibility, which is frequently stronger than that of the organs to which it is natural. And why? Because the essence of inflammation consists in accumulating the powers of the part, and this accumulation suffices for changing the mode of the organic sensibility, which differs from the animal sensibility in quantity only.

From these considerations it is evident that the distinction above established with respect to sensibility consists in the different modifications of which this power is susceptible, and not in its nature, which is every where the same. This faculty is common to all the organs; they are all of them possessed of it; it forms their true vital character; but more or less abundantly distributed to each, it gives to each a different mode of existence. No two parts enjoy it in the same proportion. In these varieties there is a degree, above which the brain is the term of it, beneath which the organ alone is sensible of the impression.

If to render my ideas on this head more clear I were to use a vulgar expression, I should say that distributed in such a dose to an organ, sensibility is animal: in such another dose, organic.*—Now that, which varies the dose of sensibility, is sometimes the order of nature, (in which way the skin and the nerves are more sensible than the tendons, and cartilages;) at other times, disease; thus in doubling the dose of sensibility to the cartilages inflammation renders them equal in this respect, and even superior to the former, and as a thousand causes may at every moment exalt or diminish this power in any part of the body it may be changed at every moment from the animal to the organic type. Hence the reason, why authors, who have made it the object of their experiments, have come to results so different; and why some of them have observed the periosteum and dura mater to be insensible, while others have put them down on the contrary as endowed with an extreme sensibility.

IV. *Of the relation which exists between the sensibility of each organ, and foreign bodies.*

Although the sensibility of each organ be subject to continual variations, it is nevertheless distributed to each by nature in a determined quantity; in a quantity to which it ever returns after its alternations of augmentation or decrease. In this respect it resembles the pendulum, which in each of its different oscillations resumes the place to which it is brought down by gravitation.

* These expressions *dose*, *sum*, *quantity* of sensibility are incorrect, inasmuch as they exhibit this vital faculty under the same point of view as the physical forces, as attraction, for example; and as they present it to us as susceptible of calculation, &c.; but, from a want of words for one science, it is necessary, in order to make it understood, to borrow them from the other sciences. There are expressions, like the words to *solder*, to *glue*, to *unglue*, &c. that are used for the want of others in the osseous system, and which really give very inaccurate ideas, unless the mind corrects the sense.

It is this determined sum of sensibility, which especially composes the life of each organ, and fixes the nature of its relations with foreign bodies; in this way the ordinary sum of sensibility in the urethra fits it for the passage of the urine, but if this sum be augmented, as in strong erection of the penis, the above relation ceases: the canal refuses passage to the urine, and suffers itself to be traversed by the semen only, which in its turn has no relation with the sensibility of the urethra when the penis is not erected.*

From hence proceeds the reason of the puckering up and spasm of the parotid, the cystic, and pancreatic ducts, as well as of the excreting tubes in general, when the molecules of any other fluid than that, which they are destined to convey are presented to them. The sum of their sensibility corresponds exactly with the nature of their respective fluids, but is disproportioned to that of any other.†—The spasmodic contraction of the larynx

* If the urine, during a perfect erection, does not go out of the bladder, it is because the contraction of the muscles of the perineum, and especially of the levator ani, prevents it. If these muscles are relaxed, though the turgescence of the corpus cavernosum and of the urethra remains the same, the urine flows out without any other obstacle than what arises from the contraction of the canal produced by the swelling of its parietes.

† These different excretory ducts do not exhibit in the mammalia any contractility. There is no stimulus which can produce it in them; I have tried them all in vain. In birds, on the contrary, the ureters and the pancreatic and biliary canals are contractile, and their motions, which return at intervals, are too well marked to be mistaken. It appears that the contractility of the excretory canals in the abdomen, is connected in these animals with the absence of the diaphragm. We know in fact that this muscle in the mammalia, assists by the pressure which it exerts, the course of the secreted fluids, and renders useless the existence of a peculiar motion in the canals which contain them. If it be however pretended that this motion exists in them, but that it

when irritated by any foreign body is produced in the same manner; for the same reason the ducts, which open upon the mucous surfaces, though at all times in contact with a variety of different fluids, are never penetrated by them.* The mouths of the lacteals, however patulous within the alimentary canal, will take up the chyle only, they reject the fluids, which are mixed with it; for with these their sensibility has no relation.

Such relations do not exist only between the different sensibility of the organs, and the different fluids of the body; but they may be exercised also between exterior substances, and the various parts of the living system. The sum of sensibility in the bladder, the kidneys and the salivary glands has a peculiar analogy with cantharides and mercury. It might be thought that the sensibility of each organ is modified, that it assumes a peculiar

is insensible, it must be allowed then, that it cannot perform the office which is attributed to it, viz. that of obliterating an opening often large enough to admit a quill. It is true, that if the orifice of one of these canals be irritated for a long time, a swelling of the membrane which lines it is sometimes produced, and the opening is then really lessened. But in these cases there is no occasion to be deceived; we see that this swelling is produced at that point by the afflux of the fluids, as it would be in any other part subjected to a similar excitement. Besides, it should be observed that the obliquity of insertion of the excretory ducts is alone sufficient to explain how the substances which pass in front of their orifices are not introduced into them. In fact these substances, at the moment of their passage, by the pressure which they exert, tend to obliterate the opening of the canal, by flattening its parietes against each other; it is thus that the pressure of the urine, upon the inferior extremity of the ureters, prevents this fluid from ascending towards the kidney. The obliteration of the opening is but an accidental thing, and most often is not even complete.

* It is not surprising, that a canal usually filled with the excreted fluids should refuse to admit another which runs in an opposite direction.

nature, and that it is this diversity of nature, which constitutes the difference of the relations of the organs with regard to bodies in contact with them ; but a number of considerations tend to prove that such difference is occasioned, not by any difference in the nature, but in that of the sum, the dose, the quantity of the sensibility, if such words may be applied to a living property. I shall adduce the following instances :—

The absorbent orifices of the serous surfaces, are sometimes bathed for months together in the fluid of dropsies, and take up nothing. But if the sensibility of these orifices be exalted by tonics, or an effort of nature, in such case it will place itself, if I may so say, in equilibrium with the fluid, and absorption will be made. The resolution of tumours presents us with the same phenomena; as long as the powers of the parts are weakened, the lymphatics refuse admittance to the extravasated substances; but if the sum of these powers be augmented by the use of resolvents, in a short time, from the action of the lymphatics, the tumour will disappear : from the same cause the blood, and other fluids are taken up with a sort of avidity at times, and at others, not at all.*

* All that is here said of the sensibility of the lymphatic vessels, which makes them sometimes admit and sometimes reject the effused fluids, is the more hypothetical, as it is not as yet proved that these vessels are the agents of absorption. It should be remarked, that the fluids that are supposed to be absorbed by them, differ essentially in their chemical composition, from the fluid that is usually found in their cavity. This fluid besides varies but very little in its composition, though its appearance is not uniformly the same; now, if it were the result of the absorption of fluids differing from each other, its composition ought also to vary as that of the chyle does, according to the nature of the aliments.

Before the lymphatic vessels were known, the principal phenomena of absorption were observed, and it was natural to attribute them to the action of the veins. This opinion was maintained for a long time

The art of the physician, then, in the use of resolvents, must consist in ascertaining the degree of sensibility

after the discovery of the lymphatics. Finally, towards the middle of the last century, Hunter being engaged in examining these vessels, which he has done more to make known than any other man, thought that they should be considered as the agents of absorption, and this opinion was soon generally admitted. If we look for the means by which he overthrew the ancient theory, we are astonished to find that it was by five experiments only. Harvey did not with equal facility obtain the acknowledgment of the circulation, and perhaps there does not exist a second example of an opinion, which was for a long time established, being abandoned so readily. It should be remarked, that physiologists had not yet recovered from the surprise produced by the discovery of a system of vessels so extensive, and yet for so long a time unknown; they were impatient to know the use of them; the veins had already the function of returning to the heart the blood brought by the arteries; they thought it would not impoverish them too much to deprive them of the faculty of absorbing, in order to enrich the lymphatics with it. Of the five experiments of Hunter, two are designed to prove that the veins do not absorb, the object of the other three is to show that the lymphatics do.

In the first experiment he injected tepid water into a portion of intestine, and the blood which returned by the vein appeared to be neither more diluted nor lighter than before. We cannot conceive how by mere inspection, it is possible to judge if the blood contains a certain quantity of absorbed water, a quantity which must be proportionably very small, if we consider the whole amount of blood that passes through the mesentric veins during the period necessary for the absorption of the fluid. Hunter in the same experiment tied the artery which went to the portion of intestine, and examined the state of the vein. It did not swell, and its blood did not become aqueous. But after this ligature, did the absorption continue to go on in this portion of intestine, which still had no doubt lymphatic vessels? This the author does not say. How moreover should he think that the vein could continue its action when the artery was tied?

In the second experiment Hunter injected milk into a portion of intestine, and was unable to discover this fluid in the blood of the mesentric veins; but at the period in which this experiment was made, mankind were very far from being able to detect in the blood a very small quantity of milk, and at the present day, with all the aid derived which he requires in the vessels for the purpose which he has in view; and in exalting or depressing this power

from chemistry, we can hardly discover in it a small quantity which is mixed directly with it. These two experiments prove then nothing against the absorption of the veins; as to those which he brings forward in favour of absorption by the lymphatics, they are not more conclusive. I shall content myself with relating one of them. He injected, into a portion of intestine that was empty, a certain quantity of warm milk, and confined it there by two ligatures. The veins that came from this portion were emptied of their blood by several punctures made in their trunk. The corresponding arteries were tied. He then returned the parts into the abdomen, and drew them out again in half an hour. Having examined them with attention, he observed that the veins were almost empty, and that they contained no white fluid, whilst the lacteals were almost full of it. But was not this white fluid that filled them chyle rather than milk? Was it not there before the injection of this liquid? In order to ascertain what takes place in the lymphatic vessels during absorption, we must begin by examining the state of these vessels before the experiment. But this is what Hunter did not do, and it is this that renders his experiment of no value. It is not very astonishing that he mistook the chyle for the milk, since milk has for a long time been mistaken for chyle. Flandrin, Professor of the Veterinary School at Alfort, has several times repeated this experiment of Hunter; but he took care before the injection of the milk to ascertain that the lymphatics contained no white fluid; and he never found any in their cavity after the experiment. I have myself many times performed this experiment, with the same precaution, and I have uniformly obtained the same results as those of Flandrin.

It would occupy too much time to examine all the reasons that have been advanced for and against the absorption of the lymphatics; I shall only relate some experiments I have made myself; but I ought first to observe, that absorption undoubtedly takes place in parts such as the eye, the brain, and the placenta in which the most minute dissection has been unable to discover any lymphatic vessel.

First experiment.—Four ounces of the decoction of rhubarb was given to a dog, in half an hour after he was killed, and it was found that more than half of the liquid had disappeared; the urine evidently contained rhubarb, but the lymph in the thoracic duct exhibited no trace of it.

Second experiment.—A dog swallowed several ounces of alcohol diluted with water; at the end of a quarter of an hour, the blood of accordingly. In this way, in different circumstances, resolvents may be taken from the class of the debilitating or stimulating remedies.

the animal had a very distinct odour of alcohol, but there was nothing of the kind in the lymph.

Flandrin made a similar experiment on a horse, to whom he gave half a pound of assafetida mixed with an equal quantity of honey. Six hours after, the horse was killed. The odour of the assafetida was very perceptible in the blood of the veins of the stomach, of the small intestines and the cœcum; but it could not be perceived in the lymph.

Third experiment.—A dog was made to swallow six ounces of a solution of Prussiate of Potash in water. In a quarter of an hour, the urine very evidently contained some of the Prussiate; but the lymph taken from the thoracic duct showed no appearance of it.

Fourth experiment.—I gave to a dog, in whom I had tied the thoracic duct, two ounces of a decoction of nux vomica. The effects of absorption were as rapid as if the duct had been open. After the death of the animal I satisfied myself, that the duct had been well tied, and that there was no other branch, as there sometimes is, by which the lymph could get to the subclavian vein.

I have varied this experiment by putting the poisonous fluid, into the rectum, the sacs of the pleura and peritoreum. The results have been uniformly the same.

Fifth experiment.—M. Delille and myself made an incision into the abdominal parietes of a dog, who had been fed very heartily some hours before, so that the lacteals might be easily seen, and we then drew out a portion of the small intestine upon which we applied two ligatures three inches from each other. The lymphatics that went from this portion of intestine were full of chyle and very distinct. They were all tied and cut. The blood vessels were also tied and cut, with the exception of an artery and a vein; the portion of intestine also was cut off beyond the ligatures, and thus it had no communication with the rest of the animal except by the vein and artery which were left. These two vessels were dissected with the greatest care, and even stripped of their cellular coat, lest there might be some lymphatics concealed in it; we then injected into the cavity of this portion of intestine a decoction of nux vomica, and we retained it there by means of a new ligature. This portion of intestine, covered with fine linen, The whole of the theory of inflammation is connected with the above ideas. It is well known that the system

was restored to the abdomen ; six minutes after, the effects of the poison were manifested with their usual intensity.

Sixth experiment.—M. Delille and myself separated the thigh of a dog from his body, leaving only the crural artery and vein, which kept up the communication between the two parts. These two vessels were dissected with care, insulated to an extent of from two to three inches, and even stripped of their cellular coat, for fear it might conceal some small lymphatic vessel. Two grains of a very active poison (the upas) were then inserted into the paw, and the effects were as sudden and as intense as if the thigh had not been separated from the body.

As it might be objected, that notwithstanding all the precautions taken, the parietes of the artery or vein might still contain some lymphatic, we varied our experiment so as to leave no doubt on this point. The artery was cut entirely off, the communication was reestablished between the two ends, by means of a leaden tube introduced into their cavity, and fixed by proper ligatures. The same was done for the vein. Thus there was no longer any communication between the thigh and the rest of the body, except by the arterial blood which came to the thigh, and by the venous blood which returned to the trunk : the poison afterwards introduced into the paw produced its effects in the ordinary time, that is in about four minutes.

From these different experiments, it is right to conclude that the minute branches of the veins possess the power of absorbing ; that they exert it on the surface of the mucous and serous membranes, and in the interior of the organs ; that the experiments that have been quoted in favour of the absorption of the lymphatics are inaccurate or incorrectly understood, and finally that there is no proof that these vessels absorb any thing but chyle.

Is it now necessary to refer to the venous branches this sensibility that has been attributed to the ultimate ramifications of the lymphatics ? But this sensibility, as we have already said, would be constantly in error ; the absorbent vessel does not select one fluid in preference to another ; all are indiscriminately absorbed, even the most irritating, those in fact whose action is sufficiently powerful to destroy the vascular parietes. Besides, the phenomenon then continues, when it is no longer possible to suppose the existence of this sensibility. After death even, the venous branches absorb still as they do during life, if they are placed in analogous circumstances ; and to do this it is evident, that an internal of the canals, which circulate the blood gives birth to a number of other small vessels, which admit only the

current must be established, which resembles the course of the blood. I shall now relate an experiment, which I made on this subject, and which I selected from many others, because it appeared to me to be very conclusive.

I took the heart of a dog that had died the day before; I injected into one of the coronary arteries some water of the temperature of 30 degrees of the centigrade thermometer. This water returned easily by the coronary vein to the right auricle, whence it flowed into a vessel or dish. I poured half an ounce of slightly acid water into the pericardium. At first the injected water exhibited no sign of acidity; but in five or six minutes it presented unequivocal marks of it.

Absorption then can take place without the assistance of this sensibility, as well as of this insensible organic mobility, which is supposed to be in the ultimate vascular extremities, in the absorbiug mouths, as they are called. But do these mouths really exist? Do the last capillary branches terminate abruptly with a laige opening on the surface of the membranes or in the texture of the organs? Can the absorbed fluids pass through their parietes as oxygen does in the lungs to arrive at the blood which it modifies? We are unable to make experiments on these small vessels, that are not cognizable by our senses; let us make them on the large ones, and if they permit fluids, in which they are immersed, to pass through them, for a stronger reason we may suppose that it takes place in the capillaries, whose parietes are so much more delicate and consequently more permeable. Now we have confirmed by experiments what we had suspected; the first attempts were made on dead vessels.

I took a portion of the external jugular vein of a dog; I stripped it of the surrounding cellular texture; I attached to each of its extremities a glass tube, by means of which I established a current of warm water through its interior; I then immersed the vein into a liquor slightly acid.

It is seen by the arrangement of the apparatus that there could not be any communication between the internal current of warm water and the external acid liquor.

During the first minutes the liquid that I collected did not change its nature; but after five or six minutes the water became perceptibly acid; absorption had taken place.

The same experiment was repeated on veins taken from human serous part of this fluid. Why do not the red globules pass into the serous vessels, though there exist a conti-

subjects; the effect was the same; it was the same also with the arteries, but a little slower from the greater thickness of their coats.

It remained to be seen if in a living animal absorption thus took place through the parietes of a large vessel. I know that the textures that were permeable after death, are almost all so during life, though the contrary is generally believed. If we inject into the pleura of a living animal a certain quantity of ink, at the end of an hour, and often sooner, we shall find the pleura, the pericardium, the intercostal muscles, and the surface of the heart itself, evidently of a black colour. It is true that the signs of this exudation are not always apparent. Thus after death, the transudation of the gall bladder is rendered evident by the colouring of the neighbouring parts. During life, on the contrary, as fast as the colouring particles are deposited, they are absorbed by the serous membrane which covers the surrounding parts, and carried off by the sanguineous current which runs through this membrane and the subjacent organs.

From these considerations we must believe that absorption may take place through the parietes of the vessel during life as after death. To be satisfied of this I made the following experiment;

I took a young dog of about six weeks old. At this age the vascular parietes are delicate, and consequently more likely to render the experiment successful. I laid bare one of the jugular veins; I insulated it perfectly in its whole length; I stripped off carefully every thing which covered it, and especially the cellular texture and some small vessels that ramified on it; I placed it on a card, that it might not be in contact with the surrounding parts; I then let fall, on its surface and opposite the middle of the card, a thick aqueous solution of an alcoholic extract of nux vomica, a substance the action of which is very powerful on dogs; I took care that none of the poison could touch any thing but the vein and the card, and that the course of blood was free in the interior of the vessel. Before the fourth minute, the effects that I expected appeared, at first feeble, but afterwards with so much power as to render inflation of the lungs necessary to prevent the death of the animal. I repeated this experiment on an adult animal of a much larger size than the preceding one; the same effects appeared but slower, on account of the greater thickness of the parietes; they began to appear in fact after the tenth minute.

After satisfying myself with this result respecting the veins, I thought nuity of canal? The cause by no means consists in the disproportion of the vessels to the globules as Boerhaave

I would ascertain if the arteries exhibited analogous properties. These vessels are in a less favourable condition; their texture is less spongy than that of the veins and with an equal caliber, their parietes are much thicker. It was easy then to foresee, that if the phenomenon of absorption showed itself, it would appear much slower than in the veins; this was confirmed in an experiment on two large rabbits, in whom I dissected perfectly clean one of the carotid arteries. It was more than a quarter of an hour before the solution of nux vomica passed through the parietes of the artery. As soon as I saw the symptoms of poisoning distinctly, I stopped moistening the vessel; yet one of the rabbits died. In order then to convince myself that the poison had really passed through the arterial parietes, and that it had not been absorbed by small veins which might have escaped my dissection, I carefully detached the vessel that had been used in the experiment; I cut it open in its whole extent, and I made those who assisted me taste a little of the blood, that was still adhering to the internal surface; they all perceived in it, and I did myself, the extreme bitterness of the extract of the nux vomica.

To these experiments may be objected a fact that is observed, which is, that absorption does not take place the same under all circumstances; its activity is redoubled or diminished, according to the state of some other functions. Thus during a paroxysm of fever, a medicine, which would usually act with great effect, often produces, when given in a double or treble dose, no perceptible effect. Now if absorption, was a purely mechanical phenomenon, would it undergo modifications in relation with those of the vital functions? Without doubt it would; for these modifications of the functions may introduce new physical circumstances favourable or injurious to the production of a mechanical phenomenon. Thus in the present case, the state of fever, by accelerating the circulation distends with blood the arteries and the veins. The fluid that is to be absorbed must pass from the exterior to the interior of these vessels. Now it may be easily conceived, that the quantity of blood which they contain must have a great influence upon the production of the phenomenon by the greater or less degree of tension of their parietes. This is moreover completely confirmed by experiment.

We can, without producing a very great disturbance in the functions, increase at pleasure the quantity of fluid which passes through the has taught. The breadth of the white vessels might be double or triple that of the red vessels, and still the

blood-vessels, by carefully injecting into the veins water the temperature of which is near that of the blood. An artificial plethora is thus produced, followed by very curious phenomena, of which I shall have occasion hereafter to speak. One day while making this experiment, the idea occurred to me of seeing what influence the plethora thus produced would exert upon the phenomenon of absorption.

In consequence, after having injected into the veins of a dog of middle size about a quart of water, I placed in the pleura a small dose of a substance, the effects of which were well known to me. These effects did not show themselves till many minutes after the period in which they usually appear. I soon made the same experiment on another animal with the same result.

In many other trials the effects showed themselves at the period in which they ought to have appeared; but they were evidently weaker and prolonged much beyond the ordinary time.

Finally, in another experiment in which I had introduced as much water as the animal could bear and live, the effects did not appear at all. I waited nearly half an hour for effects which commonly show themselves in two or three minutes. Presuming then that the distension of the vessels prevented the absorption, I endeavoured to satisfy myself of it, by seeing if after the distension had ceased, absorption would be any longer prevented. In consequence, I bled the animal copiously from the jugular, and I saw, with the greatest satisfaction, the effects appearing as the blood flowed out.

It was proper to make the opposite experiment, that is to say to diminish the quantity of blood, in order to see if absorption would take place sooner. This took place in fact, as I thought it would; about half a pound of blood was taken from an animal; the effects, which did not usually appear till after the second minute, showed themselves in thirty seconds.

Yet it might still be suspected, that it was less the distension of the blood-vessels than the change of the nature of the blood that opposed absorption. To remove this difficulty I made the following experiment; a dog was bled copiously; the place of the blood which he had lost was supplied by water at the temperature of 40 degrees of the centigrade thermometer, and a certain quantity of a solution of nux vomica was introduced into the pleura. The consequences of it were as prompt and as powerful, as if the nature of the blood had not been globules of the latter colour would not pass into them, if there were not to exist a relation between the sum of the

changed; it was then to the distension of the vessels that must be attributed the want or diminution of absorption.

The consequences that may be deduced from the experiments I have just related will acquire new force, if we connect with these facts a multitude of pathological ones, which are every day seen; such as the cure of dropsies, engorgements and inflammations by bleeding; the evident want of action of medicines at the moment of a violent fever, when the vascular system is powerfully distended; the practice of certain physicians who purge and bleed their patients before administering active medicines to them; the employment of cinchona at the period of remission for the cure of intermittent fevers; general or partial oedema from organic disease of the heart or lungs, and the application of a ligature upon the extremities after a puncture or a bite of a venomous animal, to prevent the deleterious effects which are the consequence of it.

On the whole, I think, it may be concluded from the preceding experiments that the capillary attraction of the small vessels is one of the principal causes of the absorption called venous. If the lymphatics do not appear to enjoy in the same manner the faculty of absorption, it probably arises not from the nature of the parietes, the physical properties of which are nearly the same as those of the veins, but from the want of a continuous current in their interior.

In this note I have brought together the absorption of the gases and that of fluids. This resemblance holds only as it relates to the permeability of the textures by these two orders of bodies. As to the cause of the absorption of the two, it cannot be the same, since gases are not subjected to capillary attraction.*

* *Note by the Translator of Magendie's Additions.*—In the preceding note M. Magendie has not done justice to Mr. Hunter. Without entering at all into the examination of the question, whether absorption is performed by the lymphatics or the veins, it is due to Mr. Hunter to contradict the assertion, that "he overthrew the ancient theory by *five experiments only*." He was not a man who adopted his opinions loosely or on slight grounds, and in the present case he performed between twenty and thirty judicious and satisfactory experiments, in the presence of several physicians and surgeons. It is true that these were performed on five different animals only, but if the result were uniform, this number was as good as five thousand or any other one that could be named. G. H.

(See Hunter's Commentaries and Cruikshank on the Absorbents.)

sensibility of the vessels, and the nature of the globules. Neither will the chyme pass into the Choledochus, though the diameter of this canal be very much larger, than that of the attenuated molecules of the aliments. Now in the healthy state, the quantity of sensibility in the white vessels being inferior to that in the red ones, it is evident that the relation necessary to the admission of the coloured globules cannot exist. But if any cause should exalt their powers, their sensibility will be on a par with that of the latter set of vessels, and the passage of the fluids till then refused, will take place with facility.

Hence it happens, that those surfaces, which are the most exposed to such agents as exalt the sensibility, are also the most subject to local inflammation, as may be remarked in the conjunctiva and the lungs; at which time such is usually the increase of sensibility in the part, that of organic, which it was, it becomes animal, and transmits to the brain the impressions, which are made upon it.

Inflammation lasts as long as there subsists an excess of sensibility; by degrees it diminishes, the red globules cease to pass into the serous vessels and resolution takes place.

From this it may be seen that the theory of inflammation is only a natural consequence of the laws, which preside over the passage of the fluids into their respective tubes; hence also it may be easily conceived how unfounded are all hypotheses, which are borrowed from hydraulics, a science, which never can be really applied to the animal œconomy, because there is no analogy between a set of inert tubes, and a series of living ducts.*

* Those theories no doubt are very incomplete that are borrowed from hydraulics, and probably will be so for a long time; but it arises from this, that the science on which it is founded, hydrodynamics, is still

I should never have finished were I to enumerate the consequences of this principle in the phenomena of the living man. The reader will easily enlarge the field of these consequences, the whole of them will form almost all the great data of physiology, and the essential points of the theory of diseases.

But no doubt it will be asked, why the organs of the internal life have received from nature, an inferior degree of sensibility only, and why they do not transmit to the brain the impressions, which they receive, while all the acts of the animal life imply this transmission? the reason is simply this, that all the phenomena, which establish our connexions with surrounding objects ought to be, and are in fact under the influence of the will; while all those, which serve for the purpose of assimilation only, escape, and ought indeed to escape such influence. Now for a phenomenon to depend upon the will, it is evidently requisite that the individual be possessed of a consciousness of such phenomenon, to be withdrawn from the influence of the will, there should exist no such consciousness.

but little advanced. A great advance will unquestionably be made in physiology, when we shall arrive at a knowledge of the course of a fluid in a system of canals, which have the same physical conditions as the system of arterial and venous vessels. But it will be a long time before science will have arrived at that point. Is it necessary for this to make no use, in the explanation of the circulation, of the few facts which are known upon the course of the fluids? Is it necessary to enter entirely into the field of hypothesis, to suppose in the small vessels a sensibility and a contractility which evidently do not exist in the large ones? I cannot believe it, and I think even that if this hypothesis should be true, and if there should be demonstrated for the capillary vessels, those properties which are attributed to them, and which would have an influence on the course of the blood, we should then know but one of the conditions of this very complicated problem, and this would not in any degree do away the necessity of knowing all the mechanical conditions.

V. *Of the two kinds of contractility, the animal, and the organic contractility.*

Contraction is the ordinary medium, by which the motion of the animal organs is effected; some parts, however, move by dilating themselves, as the iris, the corpora cavernosa, the teat and others; so that the two general faculties, from whence spontaneous motion is derived, are contractility and active extensibility; the latter of these should be carefully distinguished from passive extensibility, of which in a short time we shall speak. The first is a property of life, the second a property of texture; but as yet there exist too few data upon the nature and mode of the motion resulting from the former; it is exemplified in too small a number of organs, for us to be enabled to pay much attention to it in these general considerations.—Accordingly we shall occupy ourselves only upon the subject of contractility; with respect to that of active extensibility, I refer to the writings of the physicians of Montpellier.

Spontaneous motility, a faculty inherent in living bodies, as well as sensibility, possesses two great modifications, which differ very much from each other, accordingly as it is examined in the phenomena of one or the other life. There is an animal contractility, and there is an organic contractility.

The one being essentially subject to the influence of the will, has its principle in the brain, receives from the brain the irradiations, which put it in action, and ceases to exist when the organs, in which it is observed, communicate no longer with the brain; it participates besides at all times with the state of the brain, has exclusively its seat in the voluntary muscles, and presides over locomotion, the voice, the general movements of the head, the thorax and abdomen. The other, which is not dependent on a common centre, has its principle in the moving organ itself, is a stranger to the influence of volition, and gives rise to the phenomena of digestion, circulation, secretion, absorption, and nutrition.

The two are quite distinct in all cases of violent death; such death annihilates at once the animal contractility, and allows, for a longer or shorter time, the organic contractility to be exercised; they are essentially distinct also in all cases of asphyxia; in these, the first is entirely suspended, the second remains in activity; lastly they are distinct both in artificial palsy and in that which is brought on by disease. In these, the voluntary motions cease; the organic motions are unaltered.

Both the one and the other kind of contractility are connected with their corresponding kinds of sensibility. They are a consequence of them. The sensation of external objects puts in action the animal contractility; before the organic contractility of the heart can be exercised, its organic sensibility must be excited by the influx of blood.

Nevertheless, the concatenation of these two kinds of faculties is not always the same. The animal sensibility may be exercised, and not be necessarily followed by the exercise of its analogous contractility. There is a general relation between sensation and locomotion, but this relation is not direct and actual. On the contrary, the organic contractility can never be separated from the sensibility of the same species; the re-action of the excreting tubes is immediately connected with the action, which the secreted fluids exercise upon them: the contraction of the heart must necessarily succeed the influx of the blood into it. But authors have by no means separated these two things, either in their considerations or their language. Irritability denotes at the same time the sensation excited in the organ from the contact of bodies, and the contraction of the organ in reacting upon its excitants.

The reason of this difference in the relation of the two sensibilities and contractilities to each other is very simple. In the organic life, there is nothing intermediate in the exercise of these two faculties. The same organ is the term, in which the sensation ends, and the principle from whence the contraction begins. In the animal life, on the contrary, there exists between these two acts two intermediate functions, those of the brain namely, and the nerves, and these by not being brought into action may interrupt the relation in question.

To the same cause must we refer the following observation. In the organic life there always exists a rigorous proportion between the sensation, and the contraction. In the animal life the one may be exalted or lowered, and the other not affected by such change.

VI. *Subdivision of the Organic contractility into two Varieties.**

The animal contractility is always the same in whatever part of the body it is situated. But there exist in the organic contractility two essential modifications, which would seem to indicate a difference in their nature, though

* Even in reasoning according to the hypothesis of Bichat, and admitting the existence of this organic sensibility, it would always be inaccurate to say, that the contraction is uniformly in proportion to the sensation. How is it to be known in fact? Since this sensibility is not transmitted to a common centre, it might very well be excited without our being informed of it by any apparent effect. Sometimes also a very evident contraction would correspond to the slightest excitement.

there be only diversity in outward appearances. This difference is sometimes visible, at other times though really existing, it cannot be seen by inspection.

The sensible organic contractility may be observed in the heart, in the stomach, intestines, bladder,* and other

* The contractility in the different organs in which we can observe it does not exhibit characters so striking as those which Bichat here assigns to it, and the motions which he ranks in the same class have the greatest differences among them. To be convinced how little justice there is in this division, it will be sufficient to trace the progress of the food, along its whole course, to the interior of the digestive canal. The first act which is presented to our observation is entirely voluntary; this is mastication; the act which follows it is not so completely so. Deglutition in fact can sometimes take place against the will, if a body of a proper consistence is at the entrance of the pharynx. We have but an imperfect control over the muscles of the uvula and the velum palati, if we wish to move these parts separately; we have perhaps less power still over the contraction of the muscles of the pharynx, though they do not appear to differ from the locomotive muscles, either in their symmetry, or in the arrangement and colour of their fibres, or in the nerves which they receive; nor finally do they differ in the sudden, instantaneous contraction, wholly different from the slow contraction, the vermicular motion of the stomach and intestines.

After having passed the pharynx, the alimentary mass enters the œsophagus. The motions are there still under the influence of the nerves; but they are not at all under the influence of the will. The muscular layer which produces them has not the appearance, the red colour of the voluntary muscles; but it still preserves something of the sudden motion of their contraction. Hence we see, that the motions of the œsophagus cannot be ranked either among the motions of organic life, since they cease by the division of the nerves, or among those of animal life, as they are not under the influence of the will. It is remarkable also that Bichat, who, in this and the following paragraph, announces the characters of the different kinds of contractility, does not speak of the œsophagus, whilst he offers as an example the motions of the bladder, the heart, the stomach and the intestines.

When Bichat wrote this work, hardly any thing of the motions of the œsophagus was known, except from the writings of Haller, who made but four experiments on the subject. I wished to observe them organs. It is exercised upon very considerable quantities of the animal fluids.

myself, and I have discovered many facts which I think interesting ; I shall relate them here as I described them in a memoir read to the Institute in 1813. Before attempting to ascertain what part the œsophagus took in the passage of the food, it was proper to ascertain its state when it was supposed to be at rest. In the first experiments, I noticed an important phenomenon, and which hitherto had escaped the observation of physiologists, viz, that the lower third of the œsophagus has constantly an alternate motion of contraction and relaxation, which appears to be independent of all foreign irritation. This motion appears to be confined to the portion of the tube which is surrounded by the plexus of nerves of the eighth pair, that is to say, to about its lower third ; there is no trace of it in the neck nor in the superior part of the thorax. The contraction appears like a peristaltic motion, it begins at the junction of the superior two thirds with the inferior third, and is continued to the insertion of this tube in the stomach. When the contraction is once produced, it continues for an uncertain time ; usually it is less than half an hour. The œsophagus contracted in this way in its lower third is hard like a cord powerfully stretched. Some persons whom I have made feel of it in this state have compared it to a rod. When the contraction has lasted the time I have just mentioned, the relaxation takes place suddenly and simultaneously in each of the contracted fibres ; in some cases, however, the relaxation seems to take place from the superior fibres towards the inferior ones. The œsophagus examined during the state of relaxation exhibits a remarkable flaccidity, which contrasts wonderfully with the state of contraction.

This alternate motion is dependent on the nerves of the eighth pair. When these nerves are cut in an animal, this motion entirely ceases ; the œsophagus contracts no more, but it is not in a state of relaxation ; its fibres without the control of nervous influence shorten ; it is this which produces, so far as the touch is concerned, an intermediate state between contraction and relaxation.

When the stomach is empty or half full of food, the contraction of the œsophagus recurs at much longer intervals ; but if the stomach be powerfully distended by any cause, the contraction of the œsophagus is usually very powerful, and continues for a much longer time. I have seen it, in cases of this kind, continue more than ten minutes ; under the same circumstances, that is to say, when the stomach is excessively full, the relaxation is always much shorter.

If during the time of contraction, we wished, by mechanical pressure

The insensible organic contractility is that, by virtue of which the excreting tubes re-act upon their respective

made on the stomach, to make a part of the aliments which it contained pass into the œsophagus, it would be necessary, in order to accomplish it, to employ a very considerable force; and often even we should not succeed. It seems that pressure increases the intensity of the contraction, and prolongs its duration. If, on the contrary, the stomach is pressed during relaxation, it is very easy to make the substances it contains pass into the cavity of the œsophagus. If it be a liquid, the slightest pressure, sometimes even its own weight, or the tendency which the stomach itself has to contract, will bring about this result. When the stomach is laid bare and distended above measure, fluid does not usually enter into the œsophagus, because, as we have said, the distension of the stomach is a cause which prolongs the contraction of the œsophagus.

The passage of a fluid in the œsophagus is usually followed by its entrance into the stomach. Sometimes however the fluid is thrown out. When it goes into the stomach, the œsophagus contracts nearly the same as in deglutition, sometimes almost immediately after it has entered it; at other times the œsophagus allows itself to be considerably distended before it pushes it into the stomach.

It was at the moment of deglutition that Haller observed the motions of the œsophagus, and the description which he has given of them is very accurate for the two superior thirds of the canal; but the action of the inferior third is essentially different; and this distinction seems to have escaped him. Haller says that the relaxation of each circular fibre immediately follows the contraction; and this is true of the portion of the canal situated in the neck and in the superior part of the thorax; but it is not accurate for the inferior portion, in which we see that the contraction of all the circular fibres is continued long after the entrance of solids or fluids into the stomach. At this moment the mucous membrane of the cardiac extremity of the œsophagus, pushed by the contraction of the circular fibres, forms a very considerable projection into the cavity of the stomach. The contraction usually coincides with the period of inspiration, when the stomach is more strongly compressed; the relaxation takes place most often at the time of expiration. When the aliments have once entered the stomach, it is this contraction of the inferior part of the œsophagus which opposes their return. The resistance that is offered at the other orifice is not of the same species. In living animals, whether the stomach be empty or full, the pylorus is uniformly shut by the contraction of its fibrous fluids, the secreting organs upon the blood, which flows into them, the parts where nutrition is performed upon

ring and the contraction of its circular fibres. There is frequently seen in the stomach another contraction, at one or two inches distance, which appears to be designed to prevent the aliments from arriving at the pylorus. We perceive also irregular contractions, beginning at the duoderum, and extending to the pyloric portion of the stomach, the effect of which is to push back the aliments towards the splenic part.

The aliments remain in the stomach long enough to undergo no other modifications than those which result from their mixture with the perspiratory and mucous fluids, which are constantly found in it and renewed there. During this time the stomach remains uniformly distended ; but afterwards the pyloric portion contracts in its whole extent, especially in the part nearest the splenic portion, towards which the aliments are carried. Then there is found, in the pyloric portion, only the chyle mixed with some unchanged aliments. When there is accumulated in this part a quantity of it, which is never very considerable, there is seen, after a moment of rest, a contraction at the extremity of the duodenum ; the pylorus and the pyloric portion soon take part in this motion, and the chyle is forced towards the splenic portion ; but afterwards the motion is in an inverse direction. The pyloric portion, which allowed itself to be distended, contracts from left to right, and directs the chyle towards the duodenum, which soon passes the pylorus and enters the intestine. The same phenomenon is repeated a certain number of times, then it ceases, and commences again after sometime. This motion, when the stomach contains much food, is limited to that part of the organ nearest the pylorus; but as it becomes empty, the motion extends, and appears even in the splenic portion when the stomach is almost entirely evacuated. In general; it becomes more evident at the end of chylification.

The motion which produces the progression of the chyle in the small intestines is very analogous to that of the pylorus; it is irregular, made at variable intervals, it is sometimes in one direction and sometimes in another, and sometimes appears in many parts at once ; it is always more or less slow, it produces changes of relations in the intestinal circumvolutions. and it is entirely beyond the influence of the will.

We should form a very false idea of the motions of the small intestines during digestion, if we judged of them by those which these intestines exhibit in an animal recently killed. In this case, it is not the annular fibres only that enter into action, so as to exhibit, by their the nutritive juices, and the lymphatics upon the substances which excite their open extremities; upon all these

successive contractions, a vermicular motion. The longitudinal fibres act also in a very conspicuous manner, and produce a rolling of the intestinal circumvolutions, which change their relations at every instant. These motions are never more evident than when the whole mass of intestines is removed from a living animal.

The motions of the large intestines have nearly the same characters as those of the small intestines, like these last, they are not always in the same direction, but push the substances which are contained in their cavity, sometimes towards the ileum and sometimes towards the anus. But by means of this motion, these substances which have already the character of *feces*, can never re-enter the small intestines. The cause that prevents their return is different from that which prevents the return into the stomach of the substances contained in the duodenum. The obstacle in this case, we have said, is produced by the contraction of the contractile rings, which are found at the extremity of the two cavities; in the other, it is produced by a cause purely mechanical, by the arrangement of the ileo-cecal valve. Hence it follows, that if the mode of contraction of the different parts of the intestinal canal be perverted by any cause, it might happen that their contraction towards the pylorus would not take place when the duodenum was affected with its anti-peristaltic motion, and then the substances contained in it, pushed by the contraction of the annular fibres, would re-enter the stomach. At the coecum, on the contrary, as the obstacle is purely mechanical, so long as the ileo-coecal valve is not broken, it will present an insurmountable obstacle to the return of the *feces* into the small intestines.

The motions of the large intestines, sufficient to carry the feces into the rectum, would not, in a state of health, be powerful enough to expel them entirely, by overcoming the resistance which the sphincter constantly presents; in expelling the fecés, the contraction of the intestine is assisted by the pressure which arises from the lowering of the diaphragm, and by the contraction of the abdominal muscles.

We have just pointed out the motions which carry the alimentary mass along the intestines. We may see that they have but little resemblance among them. The only character that is common to them is that of not being under the influence of the will. Yet there is an exception to this in some individuals who possess the faculty of ruminating. (The will is seen exerting itself on the production of other *sensible organic motions*. Bayle could stop at will the pulsation of his occasions, wherever the fluids are disseminated in small quantities, or are very much divided, this second species of contractility is brought into exercise. A tolerably

heart.) If we examine the motions of the digestive tube when it is free of aliments, we see their difference in a manner not less striking. The œsophagus exhibits those alternate motions that we have described; a very powerful contraction of its inferior third, and then suddenly the most complete relaxation. In the stomach we see only some undulations, that go irregularly from one orifice to another. In the intestines, these motions exhibit nearly the same regularity, but the groove formed by the contraction of the annular fibres is deeper, and the undulatory motion is not so slow. If a stimulating medicine is introduced into the stomach, these contractions become more evident, and the motions more rapid; but they always preserve the same character. The contraction takes place progressively, and never in the sudden manner of a muscle of locomotion. Of all the substances which can be used to ascertain these motions, there is no one whose action is more efficacious than veratrine, a new vegetable alkali extracted from the *veratrum sabadilla.* If the external parietes of the digestive tube be excited by any stimulus, by touching it with the finger, by a puncture, or by the galvanic fluid, there is in the œsophagus a sudden contraction of the longitudinal and circular fibres, which narrows the organ and shortens it at the same time; the relaxation takes place instantaneously and in as striking a manner. In the stomach, no motion is perceived in the direction of its length; we see only an annular contraction, which is developed slowly at the excited point, and which is usually not transmitted to the neighbouring parts. In the intestines, the excitement produces a very decided contraction, and very often in the neighbouring parts a kind of peristaltic motion; but this motion is always slow and does not at all resemble the sudden contraction of the œsophagus.

The difference between the motions of the œsophagus and those of the other parts of the intestinal canal is very remarkable in birds. In them the œsophagus appears to be entirely membranous; and yet it contracts like a muscle of locomotion; whilst the stomach, which has red muscles very similar to the locomotive muscles, has slow, gradual vermicular motions, like all the canal which is below it.

There exists finally between the motions of the intestinal canal a difference relative to the manner in which they terminate. Those of the intestines, but little sensible during life, acquire at the moment of death a very great intensity; whilst those of the œsophagus, before so distinct, cease immediately, and in the most complete manner.

precise idea may be given of both, by comparing the one with attraction, a power which is exercised upon the great aggregate of matter, and the other with the chemical affinities, the phenomena of which take place in the molecules of different substances. For the purpose of explaining this difference, Barthez has compared the one to the second hand of a watch, which traverses the circumference in a very apparent manner, and the other to the hour hand, which moves also, but whose motion is not distinguishable.

The sensible organic contractility nearly answers to the irritability of authors; the insensible organic contractility to what is called tonicity. But these words seem to suppose in the properties, which they indicate a difference of nature, while this difference exists only in appearance. I therefore prefer employing for both a common term. It designs their general character, that of appertaining to the interior life, and their independence with regard to the will. To this term I join an adjective expressive of the particular attribute of each.

In fact we should possess a very inaccurate idea of these two modes of action, were we to consider them as proceeding from different principles. The one is but the extreme of the other; they are both connected by insensible gradations. Between the obscure but real contractility, which is necessary to the nutrition of the nails, and the hair, &c. and that which we see in the motions of the stomach, and intestines, there exist innumerable shades of this property, which serve as transitions betwixt its perceptible degrees; such are the motions of the dartos,* of the arteries, and of certain parts of the cutaneous organs.

* It is not the dartos that contracts in the motions of the scrotum, it is the skin itself that produces that vermicular motion that is observed

The circulation will give us a very good idea of this graduated enchainment of the two kinds of organic contractility. The sensible organic contractility presides over this function in the heart and large vessels,† by

in this part. This motion can be produced by stimuli of very different kinds; by the impression of cold, by pinching the skin or by fear. I have seen these motions so great in a man on whom I was about to operate for hydrocele, that I was obliged to wait for a long time for fear of wounding the testicle, which, by those motions, ascended and descended precipitately.

† It might be thought from this expression, that Bichat supposed that the great arteries influenced the course of the blood by an active contraction analogous to the muscular contraction; but this was not his opinion. He only wished to say, that the blood continued to move in the great arteries solely by the influence of the heart. This contraction of the great arterial trunks has been heretofore maintained by many anatomists, and is even at present by some. There are at the present day three principal theories relative to the circulation.

In the first, it is contended that all the parts of the arterial system are irritable, and that they contract like the muscular texture; many even add that they can dilate spontaneously, as takes place every instant in the heart. According to this supposition, the arteries alone would be able to continue the course of the blood.

In the second opinion, which is that of Harvey, and which is still adopted, more particularly by the English physiologists, it is affirmed on the contrary, that the arteries are not contractile in any point; that if they do contract in certain cases, it is in virtue of that property common to all the solids, by which they return upon themselves, when the cause that has distended them ceases to act. The partisans of this opinion conclude that the arteries have not and cannot have any influence upon the motion of the blood which runs through them, and that the heart is the principal, and as it were, the sole agent of the circulation.

Finally the third opinion, that which now prevails most generally in France, consists in a union of the two preceding ones; the trunks and principal arterial branches are considered as incapable of acting upon the blood; but this property is attributed to the small arteries, and it is thought to be very great in the last divisions of these vessels. Thus, in this mixed opinion, the blood is carried by the sole influence of the degrees it become less apparent, in proportion as the diameter of the vascular system decreases; and lastly, it

heart in all the arteries of a considerable size; it is moved in part by the influence of the heart and in part by that of the parietes in the smaller arteries, and finally it is moved by the sole action of the parietes in the last arterial divisions. This action of the small vessels is also described as the principal cause of the course of the blood in the veins.

In a question of this nature our opinion should be determined by experiments alone. This presents many points for elucidation.

The first and the easiest to be decided is to ascertain if the arteries are or are not irritable. The problem was in some measure resolved in relation to the great arteries by the experiments of Haller and his disciples, by Bichat himself, and by those which M. Nysten has made upon man. For the purpose of being more perfectly convinced, I have sought, by all the known means, to develop the irritability of the arterial parietes; I have successively subjected them to the action of pricking instruments, of caustics and of galvanism, and I have never perceived any thing which resembled a phenomenon of irritability; and as those who maintain the irritability of the arteries pretend that if we do not perceive the contractions, it is because the experiments are made on too small animals, in whom the effects are but slightly apparent in consequence of the small diameter of these canals, I have repeated the experiment on large animals, on horses and asses, and I have never observed any other motions than the communicated motions.

As the great arteries show no contraction, we ought to believe that the small ones would not; but as among the physiologists who reject the irritability of the arterial trunks, some like Haller, do not speak of the branches, others accord to them contractility, it becomes necessary to test this question by experiment; now these small vessels, like the larger ones, remain perfectly immoveable under the action of the scalpel, caustics and a stream of galvanic fluid.

Irritability does not exist then in the large or the small arteries. Respecting the last arterial divisions, as the vessels which form them are so small that they cannot come under the cognizance of the senses, at least in a state of health, no one can affirm or deny that they are irritable. Yet from analogy we ought to conclude, that they have no sensible motion. In cold-blooded animals, in fact, it is easy to see the blood circulating in these vessels, and even passing into the veins; now the vessels themselves appear to be completely immoveable.

As the arteries cannot act upon the blood by contracting in the is insensible in the capillary tubes, where tonicity only is observed.

manner of muscles, must we conclude that they have no action upon this fluid, and that they are in relation to it nearly like inflexible canals? I am very far from thinking so. If in fact the arteries had no influence upon the blood, this fluid, moved by the sole impulse of the heart, would, from its incompressibility, be alternately in motion and at rest. This is indeed what Bichat thought, and what he has advanced in his other works; it is what has been since maintained in a more formal manner by Dr. Johnson of London. It is however very easy to prove that it is not in this way that the blood is moved in these vessels. Open a large artery in a living animal, and the blood will escape in a continuous jet, but by jerks; open a small artery, and the blood will flow out in a continuous and uniform jet. The same phenomena take place in man if the arteries are opened, either by accident or in surgical operations. The heart being unable to produce a continuous flow, since its action is intermittent, it must be then that the arteries act upon the blood; this action can only be the disposition which they have to contract, and even to obliterate their cavity entirely. Bichat thought that this tendency to narrowing was not sufficient in the arteries to expel the blood contained in their cavity. He maintains that the vessel does not contract upon itself only when the blood has ceased to distend it. If it were so, the arteries would be equivalent to inflexible canals, and the course of the arterial blood would not be continuous; but we can easily demonstrate that the force with which the arteries contract is more than sufficient to drive out the blood that they contain.

When two ligatures are applied at the same time and at some centimetres distant upon two points of an artery which furnishes no branches, we have a portion of artery in which the blood is subjected only to the influence of the parietes. If we make in this portion of the vessel a small opening, almost all the blood that it contains is immediately thrown out, and the artery is much contracted. This experiment has been known for a long time, and uniformly succeeds. The following is one of my own, and places, it seems to me, the phenomenon in a very clear light. I laid bare the crural artery and vein of a dog to a certain extent; I passed under these vessels, near the trunk, a string, which I afterwards drew tightly at the posterior part of the thigh, so that all the arterial blood should come to the limb by the crural artery, and all the venous blood return to the trunk by the crural vein; I then applied a

Should we consider irritability as a property inherent exclusively in the muscles, as being one of the characters

ligature upon the artery, and this vessel was very soon completely empty in the part below the ligature.

It is then satisfactorily proved that the force with which the arteries contract upon themselves is sufficient to expel the blood they contain. But what is the nature of this contraction? We have proved that it cannot be attributed to irritability. Every thing leads to the belief that it should be referred to the very great elasticity which the arterial parietes enjoy, an elasticity that is brought into action, when the heart forces a certain quantity of blood into the cavity of these vessels. This property of the arteries being known, it is easy to conceive how the principal agent of the arterial motion, being alternate, the course of fluid is yet continuous. The elasticity of the arterial parietes is similar to that of the reservoir of air in certain pumps with an alternate action, and which notwithstanding throw out the fluid in a continuous manner.

It is not enough to know the kind of influence which the contraction of the arteries has on the motion of the arterial blood; it is necessary to know if this contraction does not influence in a sensible manner the course of the blood in the veins. This is elucidated by the following experiment. Lay bare, as in the preceding experiment, the crural artery and vein of a dog; tie the limb strongly, taking care not to include these vessels; afterwards tie the crural vein, and make a small opening in it below the ligature, of one or two lines in length; the blood flows out in a continuous jet. If the artery be compressed, so as to intercept the course of blood in it, the jet still continues a short time; but it is seen sensibly to diminish, as the artery is becoming empty. It at length ceases entirely when the artery is completely emptied; and though the vein remains distended with blood along its whole extent, it does not flow out at the small wound. If the compression be taken off of the artery, the blood enters it with force, and almost at the same instant it begins again to flow from the opening in the vein, and the jet is reestablished as before. If we check the course of the blood in the artery, there is but a feeble jet from the vein; it is the same if the passage of this fluid is alternately intercepted and permitted.

I make the same phenomenon evident in another way; I introduce into the crural artery the extremity of a syringe filled with water at the temperature of 30 degrees of the centigrade thermometer; I push by which they are distinguished from other organs, and should we call this property by a name expressive of its peculiar seat in the muscle, we should conceive it, if I mistake not, in a very different way from that in which it naturally exists.

It is true, that in this respect the muscles occupy the first rank in the scale of the animal solids; they possess the maximum of the organic contractility; but every living organ acts, as they do, though in a manner less apparent upon the excitant when artificially applied, or on the fluid, which in the natural way is carried to it for the purpose of supplying the matter of secretion, nutrition, exhalation, or absorption.

Nothing in consequence is more uncertain than the rule, which is commonly adopted for pronouncing upon the muscularity of any doubtful part; for the rule consists in ascertaining whether such part does or does not contract under the action of stimuli.

It is thus, that a muscular tunic is admitted in the arteries, although their organization entirely differs from that of the muscles; it is thus, that the womb is pronounced to be fleshy, however foreign to such structure; it is thus, that a muscular texture is admitted in the dartos, in the iris, and other parts, although no such structure be observable there.

the piston slowly, and soon the blood goes out by the opening in the vein, at first alone and afterwards mixed with water, and it forms a jet the more considerable in proportion to the force with which the piston is pushed.

To prove, as we have done, that the heart maintains an evident influence on the course of the blood in the capillary vessels, is not to advance that these vessels have no action on the motion of this fluid. Many physiological phenomena, on the contrary, prove that the capillaries can aid with more or less facility the passage of the blood, and consequently sensibly influence its course.

The faculty of contracting under the action of irritating substances like that of the sensibility, is unequally distributed among the organs; they enjoy it in different degrees. We do not properly conceive it, if we suppose that it belongs exclusively to some of them. It does not, as some have imagined, possess its peculiar seat in the muscular fibre. Life is the sole condition necessary to all the fibres for enjoying it; their peculiar texture influences the sum only, which they receive of it; it appears that to such an organic texture, is attributed, if I may so express myself, such a dose of contractility; to such another texture, such another dose, and so on; so that to employ the expressions, which I have used in treating on the subject of sensibility (however improper they may be, yet capable alone of rendering my ideas) the differences in the organic contractility of our different parts, consist in the quantity only, and not in the nature of this property: indeed it is with respect to quantity only that this property varies, accordingly as it is considered in the muscles, the ligaments, the nerves, or the bones.

If a special mode of contraction ought to be designed for the muscles by a particular expression, such expression could be only derived from the property which they have of contracting from the influence of the will; but this property is foreign to their texture, and comes to them from the brain only; for as soon as they cease to communicate with this organ directly by means of the nerves, they cease also to be the agents of voluntary motion.

These considerations lead us to examine the limits which are placed between the one and the other kind of contractility. We have seen that those which distinguish the two modes of sensibility, appear to be derived only from the greater or less proportion of this power; that in a certain proportion sensibility is of the animal kind, in a certain inferior proportion, of the organic kind, and that frequently from an augmentation, or diminution of intensity the two sensibilities reciprocally borrow their respective characters. We have seen a phenomenon almost analogous to this in the two subdivisions of the organic contractility.

But this is not the case with regard to the two great divisions of contractility considered in general. The organic can never be transformed into the animal contractility. Whatever be its increase of energy, it constantly remains the same in its nature. The stomach, the intestines frequently assume a susceptibility of contraction, which makes them rise up and produces in them* the

* Under no circumstance does the stomach rise up, as Bichat calls it. We have, in a preceding note, explained the ordinary motions of this viscus, in a state of vacuity, during digestion and under the influence of an internal or external stimulus. None of these motions are sufficient to produce that sudden and energetic expulsion which characterizes vomiting. The opinion that the stomach rises up in vomiting originated in a time of ignorance, and we ought not to be astonished that it should find advocates even in our day. This has not however been uniformly adopted; Bayle and P. Chirac opposed it by experiments; Senac, Van Swieten and Duverney declared themselves against it; but Haller, by adopting it, suddenly changed the views and removed the uncertainty of a great number of physiologists, who, not taking the labour of making experiments for themselves, loved to repose on the faith of a celebrated name. In physiology the opinions of Haller are certainly entitled to very great weight; this is because this wise observer, before announcing them as a general proposition, was accustomed to repeat many times the experiments on which he founded them; but in this case he did not sufficiently question the use of the stomach in vomiting.

He has made four experiments only, less for the purpose of satisfying himself that the phenomenon existed, than to see it such as he supposed it. It is very difficult, even for the best mind, to divest itself in observing, of the ideas previously received without examination. It may then be believed, that Haller in this way saw but superficially. These considerations determined me some years since, to satisfy myself most violent motions by the most simple stimuli, but these movements preserve at all times their peculiar type, their

of what takes place in vomiting, and of the part which the stomach performs in it. I shall relate briefly the experiments which I tried on the subject. The first was made on a dog of middling size, whom I had made to swallow six grains of emetic. When this medicine had excited nausea, I cut through the linea alba opposite the stomach, and introduced my finger into the abdomen. At each nausea, I felt it very powerfully compressed above by the liver, which the diaphragm pushed down, and below by the intestines, which were compressed by the abdominal muscles. The stomach also appeared to me to be compressed; but instead of feeling it contract, it appeared to me, on the contrary, to increase in size. The nauseas became more frequent, and the more marked efforts, which precede vomiting, appeared. Vomiting finally took place, and then I felt my finger pressed with a force truly extraordinary. The stomach rid itself of a part of the aliments it contained; but I distinguished no sensible contraction in it. The nausea having ceased for a short time, I enlarged the opening in the linea alba, for the purpose of observing the stomach. As soon as the incision was enlarged, the stomach presented itself at it, and made an effort to come out of the abdomen; but I prevented it with my hand. The nauseas returned in a few minutes, and I was not a little surprized to see the stomach filled with air, as they came on. In a very little time the organ had become three times its former size; vomiting soon followed this dilatation, and it was evident to all who were present, that the stomach had been compressed without having experienced the least contraction in its fibres. This organ rid itself of air and of a portion of aliments; but, immediately after the exit of these substances, it was flaccid, and it was not till after some minutes, that gradually contracting, it became nearly of the same dimensions as it was before the vomiting. A third vomiting took place, and we saw again the same series of phenomena.

For the purpose of ascertaining whence the air came, which, during the nauseas, distended the stomach, I applied a ligature on the stomach near the pylorus, so as to close the communication which exists between this organ and the small intestines, and I made the dog swallow six grains more of emetic in powder. At the end of half an hour the vomiting returned, accompanied by the same phenomena. The distension of the stomach by air was at least as marked as in the preceding experiment; besides there was no appearance of contraction of the primitive character; and have never been regulated by the brain. From whence proceeds this difference in the

stomach, and we could not even clearly distinguish its peristaltic motion. The animal having been killed some moments after, in an experiment which had no relation to vomiting, we examined the abdomen. We saw that the stomach was of considerable size; its texture was flaccid and not all contracted; the ligature, at the pylorus, was not displaced, and the air had not been able to pass this way.

Having repeated this experiment and uniformly obtained the same results, I thought it right to conclude with Chirac and Duverney, that the mechanical pressure, exerted on the stomach by the diaphragm and the abdominal muscles, is much concerned in the production of vomiting; now, if it were so, by removing this pressure from the stomach, vomiting would be prevented; experiment confirmed this conjecture.

I injected into the vein of a dog four grains of an emetic dissolved in two ounces of common water, (in this way vomiting is produced quicker and more certainly;) I afterwards made an opening in the abdomen, and when the first efforts of vomiting began, I quickly drew out the whole of the stomach, which did not prevent the efforts of vomiting from continuing. The animal made precisely the same efforts as if he had vomited; but nothing came from the stomach; this organ remained completely immoveable. I wished then to see what would be the effect of pressure made on the stomach; for this purpose, I placed my right hand on the anterior face of this organ, and my left hand on the posterior face. The pressure was hardly commenced when the efforts of vomiting, that is to say, the contraction of the diaphragm and the abdominal muscles powerfully recommenced. I suspended the pressure; the abdominal muscles and diaphragm soon suspended their contractions. I renewed the pressure; the contractions of the muscles began again; then I suspended it; they ceased; and seven or eight times in succession. The last time, I made a strong and continued pressure; this produced a real vomiting. A part of the substances contained in the stomach was thrown off. I repeated this experiment on another dog; I observed the same facts; only I remarked moreover that the contractions of the diaphragm and the abdominal muscles can be produced by merely drawing by the œsophagus.

In the experiment just related, the emetic substance was introduced into the veins, and we have already remarked, that the effects were quicker and more certain than if the same substance had been introduced into the stomach. This alone should make us suspect that phenomena of sensibility and contractility? I cannot in a precise and rigorous manner resolve this question.

vomiting is not owing, as is generally believed, to the impression of the emetic on the mucous membrane of the stomach; for, in this case, its action ought to have been more prompt when it was placed directly in contact with this membrane, than when it arrived at it with the blood after having passed through the lungs and the four cavities of the heart. For the purpose of elucidating this question and of seeing if the contractions of the muscles were the result of the impression produced on the stomach, or if they were excited more directly by the emetic substance mixed with the blood, I made the following experiment:

I opened the abdomen of a dog, and having brought the stomach out at the opening, I tied with care the vessels that went to this viscus, and I removed the whole of it (I ascertained in some of the preceding experiments that a dog can live eight and forty hours after his stomach has been removed.) I made a suture in the abdominal parietes; then, having laid bare the crural vein, I injected into its cavity a solution of two grains of emetic in an ounce and a half of water. I had hardly finished the injection when the dog began to have nausea, and he soon made all the efforts that an animal does when he vomits. These efforts appeared to me to be even more violent and longer continued than in ordinary vomiting. The dog remained quiet about a quarter of an hour; I then renewed the injection, and I forced two grains more of emetic into the crural vein; this was followed with the same efforts of vomiting. I repeated the experiment many times and always with the same success; but this experiment suggested to me another, which I performed in the following way: I took a dog of good size, from whom I removed the stomach, as I had done in the preceding experiment; I introduced into the abdomen a hog's bladder, to the neck of which I had fixed, by threads, a canula of gum elastic; I put the end of this canula into the extremity of the œsophagus, and I fixed it there also by threads, so that the bladder resembled somewhat the stomach, and was, like it, in communication with the œsophagus. I introduced into the bladder about a pint of common water; this distended it, but did not fill it completely. A suture was made in the wound of the abdomen, and four grains of emetic were injected into the jugular vein. Nausea soon appeared, and was followed with real efforts of vomiting; finally, after some miuutes, the animal vomited up abundantly the water from the bladder.

It followed evidently from the preceding experiments, that the

VII. *Of the extensibility and contractility of texture.*

I shall now proceed to examine the properties, which depend on texture only, on the organic arrangement of

abdominal muscles and the diaphragm concurred to produce vomiting; but it remained to be ascertained, what was the part of the diaphragm in the production of this phenomenon, and what was that of the abdominal muscles.

If the diaphragm received only diaphragmatic nerves, it would be easy to resist the contraction of this muscle by dividing these nerves; but it also receives filaments from dorsal pairs, and these filaments are sufficient to support its contractions. Yet experiment shows us, that the diaphragmatic nerves being cut, the contraction of the diaphragm is very evidently diminished in power, and it may be said, without much hazard of mistake, that this muscle loses, by this division, three quarters of its contractile force. It was then useful to see what influence the division of these nerves would have on the production of this phenomenon. I made this division in the neck of a dog of three years old, and I afterwards injected into the jugular vein three grains of emetic; there was only a very feeble vomiting; another injection of emetic, a quarter of an hour after, excited no vomiting. I opened the abdomen and endeavoured to produce vomiting by compressing the stomach. The compression, though very powerful and long continued, excited no effort of vomiting; it did not even appear to produce nausea. I thought that this circumstance might be owing to the indiosyncrasy of the animal; but having many times since repeated this experiment, I have never obtained any other result.

In order to understand what part the abdominal muscles by their contractions take in vomiting, we ought to observe what takes place when these muscles are unable to act. There is but one way of coming at this, which is, to separate these muscles from their attachments at the sides of the linea alba; this we have done on many animals; we have detached successively the external oblique, the internal oblique and the transversalis, leaving on the anterior face of the abdomen only the peritoneum. When these muscles are thus removed, we can see very distinctly through the peritoneum, all that takes place in this cavity; we distinguish, for example, perfectly the peristaltic motion of the stomach and the intestines; and if the stomach contracts the fibres of the different parts. These are extensibility and contractility.

They both succeed each other, and are connected in the same way, as in the vital phenomena, the organic and animal sensibilities are related to their respective contractilities.

Extensibility of texture, or the faculty of being distended beyond the ordinary state by external impulse (and in this it is distinguished from the extensibility of

it will be easy to see it. The abdominal muscles being thus detached, I injected three grains of emetic into the jugular vein, and also immediately nausea and vomiting took place by the contraction of the diaphragm alone. It was curious to see, in the convulsive contraction of this muscle, the whole intestinal mass pushed downwards, and pressing strongly against the peritoneum, which was ruptured in some places. In this case, the linea alba, formed by a very strong fibrous texture, is the only part which resists the pressure of the viscera; its existence then is indispensable to the action of vomiting; perhaps it performs an analogous office in the ordinary state. This experiment proves that vomiting can be produced by the efforts of the diaphragm alone; this is also confirmed by the following experiment:

I detached, as above, the abdominal muscles and laid bare the peritoneum; I afterwards divided the diaphragmatic nerves, and injected an emetic into the veins. The animal had some nausea, but nothing more. Though I repeated many times the injection of the emetic, I never was able to produce any sensible effort of vomiting.

From the different experiments that we have just related, and from the facts that we made known in a preceding note relative to the motions of the œsophagus, we may conclude, without any hazard,

1st. That vomiting can take place without any contraction of the stomach.

2d. That the pressure exerted immediately on the stomach by the diaphragm and abdominal muscles, appears to be sufficient to produce vomiting, when the occlusion of the inferior part of the œsophagus offers no obstacle to it.

3d. That the convulsive contraction of the diaphragm and abdominal muscles, in vomiting from tartarized antimony and emetic substances properly so called, is the result of a direct action of these substances on the nervous system and independent of the impression felt by the stomach.

the iris,* the corpora cavernosa, &c.) This extensibility, I say, belongs to many organs. The extensor muscles are very much lengthened in strong tension of the limbs; the skin accommodates itself to tumours; the aponeuroses, as we see in ascites and pregnancy, are distended by what is accumulated beneath them. The mucous membranes of the intestines, of the bladder; the serous membranes of the greater number of the cavities present us with similar phenomena, when these cavities are full. The fibrous membranes, the bones themselves are susceptible of distension. Thus in hydrocephalus the pericranium, and the bones of the cranium, in spina ventosa and other analogous diseases, the extremities or the middle of the long bones experience a similar distension. The kidneys, the brain, and the liver, when abscesses are formed in their interior, the spleen and the lungs, when penetrated by a great quantity of blood, the ligaments in articular dropsies, in short all the organs, under a thousand different circumstances, exemplify this property; a property inherent in their texture, and not precisely depending on their life; for as long as their texture remains untouched, their extensibility subsists also, though they themselves have ceased to live.—The decomposition of the part, from whatever cause it happens, is the sole term

* The motions of the iris cannot be attributed to an active expansion of an erectile texture; they are owing to the contractions of two muscular layers, one of which is radiated and enlarges the opening of the pupil, the other is orbicular and contracts it.

The motions of the iris, like all those which have muscular contraction for their cause, can be excited for a considerable time after death by the galvanic fluid. During life, the motions of the pupil are produced in man, by the more or less vivid impression of light on the retina. But they are beyond the influence of the will; in birds on the contrary, they appear to be entirely subjected to it. In these animals, we can even after death, and on an eye entirely detached from the body, produce the motions of the iris by pricking the optic nerve.

of this extensibility, in which the organs are passive at all times, and subject to the mechanical influence of those bodies which act upon them.

There exists for the different organs a scale of extensibility, at the top of which are those which have the greatest laxity in the arrangement of their fibres, as the muscles, the skin, and cellular substance; at the bottom of the scale are those which are characterized by their density, as the bones, the cartilages, the tendons, and the nails.

We must not, however, be deceived by appearances, with regard to the extensibility of parts of the body; for the serous membranes, which at the first glance would seem to be capable of great distension, do not yield so much of themselves, as from the development of their folds. Thus the displacement of the skin, which abandons certain parts, while it spreads over tumours in the vicinity, might easily give rise to the supposition of its being capable of a much greater distension than that of which it is really susceptible.

With extensibility of texture, there corresponds a certain mode of contractility, which may be designated by the name of contractility of texture. This can only take place after a previous distension.

In general the greater number of our organs are maintained in a certain degree of tension from different causes; the locomotive muscles by their antagonists, the hollow muscles by the different substances which they enclose; the vessels by the fluids, which circulate within them, the skin of a part by that of the neighbouring parts, the alveolar parietes by the teeth which they contain. If these causes be removed, contraction supervenes; thus, if a long muscle be cut, its antagonist will be shortened; if a hollow muscle be emptied, it will contract; if an artery be deprived of its blood, it will become a ligament; if the skin be cut into, the borders of the incision will retire from each other; if a tooth be drawn, its cavity will be obliterated.

In these cases it is the cessation of the natural extension, which occasions the contraction; in other cases it is the cessation of an unnatural extension which does so. Thus, the lower belly is straitened after puncture or delivery; the maxillary sinus, after the extirpation of a fungus; the cellular texture, after the opening of an abscess, the tunica vaginalis, after the operation of hydrocele, the skin of the scrotum, after the extirpation of the voluminous testicle, by which it was distended; the sac of an aneurism, after the evacuation of the fluid.

This mode of contractility is not by any means dependent on life; it belongs only to the texture, to the organic arrangement of the part,* yet still receives from the vital powers an increase of energy. Thus the retraction of a muscle, which is cut in the dead subject, is much smaller than that of a muscle divided in the living animal; in the same way, the retraction of the skin varies; but though less evident, this contractility subsists always, and like its corresponding extensibility has no other limit than that of the decomposition of the part.

* When a patient dies after having for a long time been deprived of solid and liquid nourishment, it is not rare to find in him the stomach and intestines considerably lessened in their two dimensions, the internal cavity almost entirely effaced, the length being hardly a third of what it was before the disease. We truly say then with Bichat that is a contraction from a want of extension. But that this mode of contractility is as he says perfectly independent of life and owing only to the arrangement of parts, is what cannot be admitted. If it were so in fact, by emptying the stomach after death, we might produce a contraction similar to that which is produced during life. Now experiment shows us, that this does not take place. The stomach when emptied remains flaccid, and does not contract in any perceptible degree.

The greater number of authors have confounded the phenomena of this contractility with those of the insensible organic contractility, or tonicity. Of these I might reckon Haller, Blumenbach, Barthez and others, who have referred to the same principle the return upon themselves of the abdominal parietes, after distension, the retraction of the skin, or a divided muscle, and the contraction of the dartos from cold. The first of these phenomena is owing to the contractility depending on texture, which does not suppose the application of an irritating substance; the second, to tonicity, which is never exercised excepting when influenced by such application.

Neither have I myself in my treatise on the membranes, sufficiently distinguished these two modifications of contraction, but we evidently ought to establish between them the most decided limits.

An example will render this more sensible. Let us take for it an organ, in which there may be observed all the kinds of contractility, of which I have hitherto spoken; a voluntary muscle for instance: In distinguishing the species with precision we may acquire a clear and precise idea of each of them.

Now such muscle may enter into action first by the influence of the nerves, which it receives from the brain; here it shews its animal contractility. Secondly, it may be brought into action by the stimulus of a physical or chemical agent applied to it, a stimulus, which artificially creates a motion, analogous to that, which is natural to the heart, and other involuntary muscles;—here we have the sensible organic contractility or irritability. Thirdly, its action may be produced by the influx of fluids, which penetrate all its parts for the purpose of carrying thither the matter of nutrition, and which at the same time are the occasion of a partial oscillatory movement in each fibre, in each molecule, a movement as necessary to the function of nutrition, as in the glands it is indispensable to the process of secretion, or in the lymphatics to that of absorption.* Such action we refer to the insensible organic contractility or tonicity: Fourthly, by the transverse section of the substance or body of the muscle, may be determined the retraction of its two ends towards their points of insertion. Here the contractility of its texture is displayed.

Any one of these kinds of contractility may cease to exist in a muscle and the others may not be affected. Cut its nerves, and there will be no longer any animal contractility; but the two modifications of its organic contractility will continue to subsist. Impregnate the muscle with opium, suffer its vessels to be well penetrated with this substance and it will cease to contract under the impression of stimuli, it will lose its irritability, but it will continue to possess the tonic movements, which are occasioned by the influx of blood into it. Lastly, kill the animal, or rather let it live, but tie the vessels which go to the limb, and the muscle will in such case lose its tonic power and possess its contractility of texture only. The latter will only cease on the supervention of sphacelus.

By these examples the different kinds of contractility may be appreciated with respect to the organs where they are assembled in a smaller number than in the muscles of volition; in the heart for instance and in the intestines,

* We know that the organs are nourished, that the glands secrete, we know that certain vessels absorb (whether they be the lymphatics or not,) but we do not know, that all this is produced by *a partial oscillatory movement in each fibre, in each molecule*. No one can be certain that this movement takes place, because no one has seen it.

where there exists a sensible and insensible contractility, the organic being retrenched ; and again in the tendons, aponeuroses, and bones, where the animal and sensible organic contractilities are wanting, the insensible organic and the contractility of texture only remaining.

In general these two last are inherent in every kind of organ, the two first belonging to some in particular only; hence for the general character of living parts we must choose the insensible organic contractility or tonicity, and for the character of all organized parts whatsoever, whether living or dead, the contractility of texture.*

We shall farther remark, that this last in the same way as its corresponding extensibility possesses them, has its different degrees, its scale of intensity, the skin and the cellular substance on the one hand, the tendons, the aponeuroses, and the bones on the other, forming the extremes of this scale.

From all that has been said, it is easy to perceive, that in the contractility of every organ there are two things to be considered, namely the contractility, or the faculty, and the cause, which puts it in action. The contractility is always the same, belongs to the organ, is inherent in it, but the cause which determines its exercise may be various.

* Why invent a new word, when we have that of elasticity, which expresses for all bodies whether organic or inorganic, that tendency to resume their usual form and size, when the cause that made them change them is no longer in exercise ?

VIII. *Recapitulation of the properties of living bodies.*

A recapitulation of these properties may be seen in the following table :

	Classes.	*Genera.*	*Species.*	*Varieties.*
Properties.	1st Vital—	1st Sensibility—	1st Animal	
			2d Organic	
		2d Contractility—	1st Animal	
			2d Organic—	1st Sensible
				2d Insensible
	2d of Texture—	1st Extensibility		
		2d Contractility		

I have not inserted in this table that modification of motion, which takes place in the iris, the corpora cavernosa, &c. a motion, which precedes the influx of the blood, and which is not in such way occasioned, neither have I mentioned the dilatation of the heart,* and in a word that species of active and vital excitability, of which some parts appear to be susceptible, and my reason for this neglect, although I recognise the reality of the modification, is my want of clear and precise ideas on the subject.

From the properties, which I have now explained, are derived all the functions, all the phenomena, which are exemplified in the living œconomy. There is not one, which may not be traced to them after a strict analysis,

* Bichat here unites three sorts of motion which have no relation between them ; the systole of the cavities of the heart should be considered as a really active dilatation. The increase of size of the corpora cavernosa, which is an effect purely passive of the accumulation of blood in those parts, and which can be produced after death by artificially accelerating the circulation in them ; and finally, the motion of the iris, a motion evidently produced by a muscular contraction, excitable by galvanism or pricking the nerve.

in the same manner as in the phenomena of physics we recur to the properties of attraction, elasticity, &c.

Wherever the vital properties are in action, there is a disengagement, and a loss of caloric peculiar to the animal, which compose for him a temperature independent of the medium in which he lives. The word caloricity will hardly serve for the expression of this fact, which is a general effect of the two great vital powers in a state of action, and not produced by any especial faculty distinct from them. We do not make use of the words, digestibility, or respirability, because digestion and respiration are the results of functions derived from the common laws of the system.

For the same reason the digestive power of Grimaud suggests an inaccurate idea. The assimilation of heterogeneous substances to our organs, is not the effect of any peculiar power. The same may be said of the different principles admitted by a number of authors, who have attributed to results and functions denominations expressive of laws, and vital properties.

The proper life of each organ is composed of the different modifications, to which are submitted in each of them the vital sensibilities and mobilities, modifications, which invariably are productive of others in the circulation and temperature of the organ. Let it be noticed however, that each organ independently of the general sensibility, mobility, temperature, and circulation of the body, has a particular mode of sensation and heat, together with a capillary circulation, which being withdrawn from the influence of the heart, receives the influence only of the tonic action of the part.* But we may pass over a

* Without denying the influence which the capillary systems of the different organs have on the circulation, we have shown that even in the veins the action of the heart is felt and modifies the course of the blood.

point so frequently and sufficiently discussed by other authors.

Let it here be understood that I offer what I have said on the subject of the vital powers, only as a simple view of the different modifications, which they experience in the two lives. These detached ideas will in a short time form the basis of a more extensive work.

Neither have I recapitulated the different divisions of the vital powers, which have been adopted by authors; the reader will find them in their works, and will easily perceive the differences, which distinguish them from those, which I have adopted. I shall only observe that were these divisions clear and precise, did they suggest to all the same meaning, we should not have to regret in the writings of Haller, Lecat, Wyth, Haen, and all the physicians of Montpellier, a number of disputes of no importance to the interest of science, and surely fatiguing to the student.

CHAPTER VIII.

OF THE ORIGIN AND DEVELOPMENT OF THE ANIMAL LIFE.

If there be any circumstance, which establishes a real line of demarcation between the two lives, this circumstance undoubtedly is the mode and epoch of their origin. The organic life is active from the very first moment of our existence; the animal life begins after birth only; for without external excitants the latter is as necessarily condemned to inaction, as without the fluids of the œconomy, which are its internal excitants, the former would become extinct. But the subject, on which we are now engaged deserves a more particular discussion, and in the first place let us examine, in what manner the animal life, which for some time is absolutely null, is born as it were and developed.

I. *In the fœtus the first order of the functions of the animal life is not as yet in action.*

The instant, at which the fœtus begins to exist, is nearly that of its conception ; but this existence, the sphere of which is every day enlarged, is not the same as that, which the child is destined to enjoy after birth.

The state, in which the fœtus exists while in the womb, has been compared to that of a profound sleep. Such comparison is inexact. In a state of sleep the animal life is only in part suspended. In the fœtus it has not commenced. We have seen in fact, that this life is made up of the simultaneous or distinct exercise of the senses, of the nerves, of the brain, of the organs of locomotion, and the voice. Now in these different functions every thing in such state is inactive.

Every sensation supposes the action of external bodies upon our own, together with the perception of such action ; a perception which takes place by virtue of the sensibility of the system, which is either general or particular, for the tact is the faculty of perceiving general impressions, and has for its object to warn us of the presence of bodies, together with their common attributes, such as heat, cold, dryness, or humidity, hardness or softness. To perceive the particular modifications of bodies is the business of the senses.

Has the fœtus in utero any general sensations ? To decide this question, let us enquire whether any impressions are capable there of exercising its tact. The fœtus lives in a temperature at all times the same, swims in a fluid, and is thrown from time to time against the parietes of the womb: such are the three sources of its general sensations.

We shall now remark, that the two former are next to nothing, and that the fœtus cannot have a consciousness of the medium, in which it is nourished, nor of the heat, by which it is penetrated, for every sensation supposes a comparison between an actual and a past state of being. We are sensible of cold, only because we have experienced an antecedent heat; were the temperature of the atmosphere invariable, we should have no idea whatever of temperature. The Laplander enjoys himself in a climate, which would be pain, and death to the Negro, if suddenly transported thither. It is not at the time of the solstices, but at that of the equinoxes, that our sensations of heat, and cold are the most lively. The reason of which must be, that at the latter seasons, their varieties are more numerous, and occasion more frequent comparisons between that, which we feel and that which we have felt.

What we have now said of temperature, we may repeat with respect to the waters of the amnios: the fœtus cannot be sensible of their influence, because the contact of any other medium is unknown to it. Before bathing, we are not sensible of the air, after bathing, the impression made by it upon us is unpleasant. It then affects us because there has been an interruption of its action upon the cutaneous organ.

Is the shock of the parietes of the matrix a more real cause of excitement, than the waters of the amnios, or temperature? At first we might be inclined to answer this question in the affirmative, because the fœtus being only at intervals subject to such stimulus, there should appear to result from thence a sensation. But let us remark that the density* of the uterus in a state of pregnancy being little greater than that of its waters, the impression must be trifling. In fact the more the consistence of bodies resembles that of the medium in which we live, the less powerful will be their action upon us. Water for instance, when reduced into vapour in our common fogs, and mists, affects the tact but slightly; in proportion as it is condensed it is the cause of a livelier affection.

The air then, to the animal which breathes, is truly the general comparative term, to which he refers all the sensations of tact. If the hand be plunged into carbonic acid gas, such substance will not affect the tact because its density is little different from that of the air.

The variety then of these sensations is in proportion to the difference existing between the density of the air, and that of the bodies, which are the occasion of such sensations. In the same way, the measure of the sensation of the fœtus must be the excess of density in the matrix above that of its waters. Now such excess being very inconsiderable, the sensation of it must be very obtuse.

This assertion with respect to the fœtus will become more general if we add to it the following: namely, that the mucous membranes, which are the seat of an inward tact have not as yet begun to exercise their functions. These membranes, after birth, being continually in contact with extraneous substances, possess in these bodies

* It is unfortunate that Bichat makes use of the word density, as he seems to be ignorant of its true signification.

The resistance, which the womb offers to the fœtus that strikes against it, is wholly independent of density, and results only from the greater or less flexibility of its parietes. Cork is much less dense than mercury, and yet it offers to the finger, when pressed against it, a much greater resistance.

so many causes of irritation, which being continually repeated, become excitants to the organs: but in the fœtus there is no succession in these causes. The same urine, the same meconium, the same mucus at all times exercise their action upon the bladder, the intestines, and pituitary membrane.

From all this we may conclude, that the general sensations of the fœtus are very inconsiderable, though it should appear that the child in this state is surrounded by many of the causes, which are hereafter to beget sensations. Neither are the particular sensations of the fœtus more active; indeed they cannot be so for their causes are absent.

The eye which is closed by the pupillary membrane, and the nostrils, which are scarcely indicated, would not be capable of receiving impressions, even in the supposition that light and odour could act upon them. Applied against the palate, the tongue is in contact with nothing capable of producing savour. Were it in contact with the waters of the amnios, the effect would be the same, because as we have said, there is no sensation, where there is no variety of impression. The saliva of one person to another person possesses savour, to the individual himself it is insipid.

The ear in like manner is awakened by no sound. All is calm, every thing reposes with the little individual.

Here then we have proved, that four of the gates of sensation are shut in the fœtus; and let us now observe that the nullity of action in the senses which we have mentioned, must occasion very nearly the same nullity with respect to that of the touch.*

* Of these four sources of sensation, the first, whatever Bichat may say, exists in the fœtus before birth, and the other three, do not exist some hours after; the eye is insensible to light, the ear to sound, and the taste is not really in exercise when the first food creates in the organ an unaccustomed sensation.

In fact, this sense is especially destined to confirm the notions which are acquired by the others, and to rectify them, for the latter are frequently illusory—the touch is always the agent of truth.* In attributing to the touch such use, nature has submitted it directly to the will; light, odours, and sounds affect their respective organs independently of the will.

The exercise of the other senses precedes that of the touch, they are the occasion of it. If a man were born without sight, hearing, smell, or taste, can we conceive in what way, he would be possessed of the sense of touch?

The fœtus resembles such a man; it possesses wherewithal to exercise the touch in its hands, which are already developed, and in the parietes of the matrix. Nevertheless the fœtus is never in action, because in seeing, in hearing, in smelling, and in tasting nothing, it is not disposed to exercise the touch in any way. Its members are little better than what to the tree are its

* Philosophers and physiologists accord to the touch a great preeminence over the other senses. The senses of seeing, smelling and hearing are, say they, the sources of a thousand illusions. The touch alone is exempt from them, and even rectifies the errors which come from elsewhere; *the touch is the sense of reason.* It is undoubtedly a delightful prerogative; but let us see if it is incontestable. And first does the touch never deceive us? All children know an experiment which proves the contrary. If we cross two fingers of the same hand, and place in the angular space between their extremities a small body which touches both of them, the touch will give the sensation of two distinct bodies. It is then true that the touch may become a cause of errors; it no doubt serves to rectify those of the other senses, but do not these in their turn often defend us from the errors of the touch? If the sight were not almost constantly in exercise, the errors of touch would be much more numerous; we can judge of them by what we experience when we are in the dark. If we were to take from one man the use of his eyes, and from another that of his hands and the exercise of touch as much as possible, we should see which would be the most embarrassed, which would make the most false judgments.

branches, which do not transmit the impression of the bodies, with which they are entangled.

I shall here notice a great difference between the tact and the touch; they were formerly confounded by physiologists; the impressions of the latter are always directed by the will, those of the former do not depend on it. We shall conclude that the portion of the animal life which constitutes sensation, does not exist in the fœtus.

This nullity of action in the senses supposes the same deficiency of action in the nerves, which belong to them, and in that of the brain from whence they issue; for the business of the former is to transmit, of the latter to receive. Now without objects for transmission and reception, the two functions cannot have place.

From perception are immediately derived the memory and imagination; from these the powers of the judgment and the will. All this series of faculties then has not had a beginning in the fœtus, because the fœtus has not perceived, or had sensation. The brain exists in a state of expectation, it possesses all that is requisite for action. It does not want excitability, but stimulus. The first division of the animal life in consequence, or that, which relates to the action of exterior bodies, on the animal, has scarcely an outline in the fœtus. Let us examine whether the same be true of the second division of the animal life, or that which relates to the reaction of the living body.

II. *Locomotion exists, but belongs in the fœtus to the organic life.*

When we see the strict connexion which exists in animals, between sensation and their voluntary efforts, we might be induced to believe, that voluntary motion increases or diminishes with the increase or diminution of sentiment; for as sentiment furnishes out the materials of the will, when it does not exist, volition cannot exist: from induction to induction, it might thus be proved that in the fœtus the muscles must be totally inactive.

Nevertheless the fœtus moves, and sometimes even very strong shocks are the result of its motions. The reason why it does not produce sound, is because the medium for the production of sound is wanting. But how can we ally the inertia of the first part of the animal life with the activity of the second. It is thus.

We have seen in speaking of the passions, that the muscles of locomotion are brought into action in two manners. 1st, by the will; 2dly, by sympathy. This last mode of action occurs, when from the affection of an inward organ the brain is affected also, and occasions a motion which, in such case, is involuntary. A passion, for instance, affects the liver, the liver the brain, the brain the voluntary muscles. Here it is the liver, not the brain, which is the principle of motion: so that the muscles, though always thrown into action, immediately from the irradiations of the brain, belong nevertheless, as to their functions, sometimes to the one life, sometimes to the other.

Hence it is easy to conceive in what way the fœtus moves: with the fœtus, locomotion is not a portion of the animal life; its exercise does not suppose a pre-existent will; it is purely a sympathetic effect.

In utero the phenomena of the organic life succeed each other with an extreme rapidity; a thousand different motions are incessantly connected in the organs of circulation and nutrition. In these, every thing is energetically in action. But this activity of the organic life supposes a frequent influence exerted upon the brain by the inward organs, and consequently as many reactions on the part of the brain by sympathy upon the muscles. Besides, the brain is at such time more susceptible of such sort of influence, being much more developed than the other organs, and entirely passive on the side of the sensations.

We may now conceive what the motions of the fœtus are. They belong to the same class as many of those of the adult, which have not been as yet sufficiently distinguished. They are the same as those which are produced in the voluntary muscles by the passions; they resemble those of the man who sleeps, and who moves without dreaming, for nothing is more common than violent agitation in sleep succeeding difficult digestion. The stomach is in strong action; it acts upon the brain; the brain upon the muscles.

I might find a number of other involuntary organic motions taking place in the voluntary muscles of the adult, and consequently adducible to my present purpose; but what I have said on this subject will suffice. Let us remark only, that the organic motions, as well as the sympathetic affection of the brain, which is the seat of them, must gradually dispose this organ, and the muscles of the fœtus, the one to the perception of sensations, and the other to the motions of the animal life, which are to commence after birth. But on this head I shall refer to the memoirs of Monsieur Cabanis.

From what has been said, then, I believe we may confidently assert, that in the fœtus the animal life does not exist, and that all the actions which take place at this age, depend upon the organic life. The fœtus, indeed, has nothing of the especial character of the animal. Its very existence is that of the vegetable; and its destruction can only be said to be that of a living body, not of an animated being. Thus, in the cruel alternative of sacrificing the life of the mother, or that of the child, the choice cannot be doubtful.

The crime of destroying a fellow-creature is much more relative to his animal, than to his organic life.—We regret the being who feels, who reflects, who wills, who acts accordingly, and not the being which breathes, which is nourished, which is the seat of the circulation and the secretions. It is the former, whose violent death is accompanied with those images of horror, under which we look on homicide. In proportion then as in the series of animals, their intellectual functions diminish, is diminished also the painful sentiment which we feel at sight of their destruction.

If the blow, which terminates by an assassination the life of a man, were to destroy his organic life only, and suffer the other to subsist without alteration, such blow would be regarded with indifference, would excite neither pity for the victim, nor horror against the aggressor.

III. *Development of the animal life, education of its organs.*

A new mode of existence commences for the infant after birth; a variety of functions are added to its organic life; their aggregate become more complicated; their results are multiplied. As for the animal life, it only begins; and at this period a number of relations are established between the little individual and what surrounds him. It is then that every thing assumes with him a different mode of being, but at this remarkable epoch of the two lives, where the one is augmented by almost the half, and where the other commences only, they take upon them both a distinct character, and the aggrandisement of the first by no means follows the same laws as the development of the second.

We shall soon remark, that the organs of the internal life attain at once their perfection, and that from the instant at which they begin to act, they act with as much precision as they ever will do. On the contrary, the organs of the external life require a species of education; they arrive only by degrees at the perfection which we afterwards see in them. This important difference should be thoroughly examined. Let us begin by appreciating of what the animal life at first consists.

In examining the different functions of this life, which start at once into existence, we shall observe in their development a slow and graduated progress.—We shall see, that it is insensibly and by means of a real education that the organs attain a precision of action.

The sensations are at first confused; they transmit only general images; the eye has only the sensation of light; the ear that of sound only; the nose only that of smell. As yet there is nothing distinct in these general affections of the senses; but from habit the strength of the first impression is lessened and the particular sensations take place. The great differences of colours, sounds, smells, and savours, become perceptible; by little and little their secondary differences also are perceived, and after a certain lapse of time the child has learnt to see, to hear, to smell, to taste, and to touch.

After successfully undergoing the operation for the cataract, the patient, who has previously been totally blind, is sensible of light only, and learns by gradation to distinguish the objects which reflect it. Another person, before whom, as I have said, for the first time is exhibited the magnificent spectacle of an opera, at the first glance, perceives only a whole, which delights him, and only by degrees is able to isolate the enjoyments of which the dance, the music, and the decorations are productive.

The education of the brain is similar to that of the senses. Whatever depends upon its action, acquires the perfection, to which it is destined, by degrees only. The powers of perception, memory and imagination, which are all of them preceded and occasioned by the sensations, increase and extend in proportion as by repeated excitement they are brought into exercise.—The judgment, of which they form the triple base, associates but irregularly at first its motions, which themselves are but irregular. In a short time a greater degree of perspicuity is observed in its operations, and lastly they become precise and rigorous.

The voice and the agents of locomotion exemplify the same phenomenon: the cries of young animals at first are only an unformed sound, which possesses no sort of character: by age they are gradually modified, and after long repeated exercise affect the peculiar consonances of the species, by which, and particularly during the season of their loves, the individual of the same species is never deceived.* I do not instance the speech of man, for this is evidently the fruit of education.

In examining the newly born animal, its muscles will be seen continually in action. As every thing is new to it, every thing is an excitant to it, and makes it move; it

* This assertion is not correct, and the voice, at the earliest age, has consonances peculiar, not only to the species, but even to the individual. The man accustomed to the very striking differences of the articulate sounds of speech or the distinct sounds of music, distinguishes with difficulty the differences in cries; but the animals to whom the cry is the habitual medium of expression are not deceived in the same way; the ewe, in the midst of a whole flock, distinguishes the voice of her lamb, and this soon learns to recognize the voice of its mother.

endeavours to touch every thing, but neither progression, nor the power of standing can have place when the contractions of the voluntary muscles are so numerous. It is necessary for such, that habit shall have taught it to combine particular contractions with other particular contractions; until then it stumbles and falls at every moment.

Undoubtedly the inclination of the pelvis in the fœtus, the disposition of the femora, and the want of curvature in the spine, adapt it but little for standing immediately after birth; but with these causes is certainly also combined the want of exercise.* Who does not know, that if a limb be suffered to remain immoveable for a length of time, it loses the habit of moving, and that when afterwards its service is required, it requires a new kind of education before it can exercise its movements with any regularity or precision. The man, who for a long time should condemn himself to silence, would experience in like manner the same embarrassment in his first attempt at utterence.

From these considerations we may conclude that our exterior life, to allow myself the expression, is learnt, and requires before it can be perfected, a sort of apprenticeship.

IV. *Of the influence of society over the education of the organs of the animal life.*

Over this sort of education, which the organs of the animal life receive, society exercises a very great influ-

* The locomotive organs do not require a long education; as we see in animals whose organization, at the moment of birth, is no obstacle to motion. A young kid in an hour after, will stand on its legs, and before the end of the day we often see it skipping. The partridge runs as it comes out of the shell.

ence; it enlarges the sphere of action of some of them, lessens it for others, and modifies it in them all.

I shall first remark, that it constantly gives to some of the organs a perfection greater than naturally should be their portion. Such in fact is the nature of our occupations as always to require the especial action of some one, or other of these organs. The ear of the musician, the palate of the cook, the brain of the philosopher, the muscles of the dancer, and the larynx of the singer, receive in addition to the general education of the exterior life, a particular education.

Under these considerations, the occupations of mankind might be divided into three classes. The first would comprehend all those, which especially regard the senses, such as painting, music, and sculpture, the acts of the perfumer and the cook, and in a word all those the results of which are productive of pleasure to the senses. In the second would be ranged the occupations, wherein the brain is chiefly called into action; such as poetry, the sciences of nomenclature, the mathematics and metaphysics. The occupations of dancing, equitation, and the mechanic acts would form the third class.*

Each several occupation then of the individual, brings into permanent activity, some one organ in particular, and gives it a peculiar perfection. The ear of the musician in a piece of harmony, and the eye of the painter in a picture, distinguish many things which entirely escape the vulgar. It frequently happens that this perfection of

* The idea of classifying human occupations, according as they bring in play the organs of the senses, the intellect or locomotion, is a wild and useless one. This division besides is made in a way altogether defective, since in the first class it is the result of the occupations which put in play the organs, whatever may be the means of execution; in the second it is the occupation itself, whatever may be the results, and in the third, it is at the same time the execution and the result.

action, is accompanied in the more exercised organ with an excess of nutrition: this we may frequently observe in the muscles of the arm of the baker, in those of the inferior limbs of the dancer, and in those of the countenance of the player.

In the second place I have asserted that society contracts the sphere of action, which should naturally belong to many of the external organs. Indeed, for the sole reason that any one of them is the more occupied, the others must be less so, and lose in aptitude what is gained by the single organ. The most common observation will prove this truth at every moment.

Examine the philosopher, who in his abstract meditations, and in the silence of the closet condemns to inaction his external and locomotive powers. Examine him by chance attempting any exercise of the body, and you will laugh at his awkwardness and air of constraint; his sublime conceptions astonish, the heaviness of his movements is amusing.

Examine on the contrary the dancer, who by the lightness of his steps exhibits apparently to the eye whatever the graces of fable have set before the imagination. It might be imagined perhaps that the profoundest meditations, have been productive of such felicity of motion; but let him be conversed with, and nothing very surprising will be found in the man.

The observing mind, which analyses the different individuals of society at every moment, will be led to similar remarks. Perfection of action in the locomotive organs, concurring with a like perfection of intellect, will seldom be found.

V. *Of the laws, which regulate the education of the organs of the animal life.*

It is manifest then that society inverts the natural order of education in the animal life, and that it irregularly distributes to the different organs of this life, a perfection which they would otherwise enjoy in a more uniform proportion.

A determined sum of power, has been attributed to every individual, which sum must always remain the same, whether it be equally or unequally distributed, accordingly the activity of one organ must imply more or less inactivity in the others.

This truth will conduct us to the fundamental principles of all social education whatever; namely, that no individual at the same time, should be applied to many studies, even if it be wished that he should succeed in all of them. Philosophers have long insisted upon this maxim, but I doubt whether the moral reasons on which they have founded it, are all of them together worth this single and beautiful physiological observation by which it is demonstrated, that for the purpose of augmenting the powers of one organ, there are no other means than those of diminishing the powers of the others. On this account I shall dwell upon this observation, and prove its truth by a variety of facts.

The ear, and especially the touch, acquire in the blind man, a perfection which would hardly be credited, were not its reality proved by daily observation. The deaf and dumb possess in the eye an accuracy of sight, which is unknown to those, with whom the powers of the ear and utterance are unfolded. Little connexion with external objects, enfeebles the senses of persons who are subject to ecstasy, but gives the brain a power of contemplation, such as to make it appear, that every part of the animal life, excepting that organ, during such affection is in a state of sleep.

But what occasion is there for seeking in extraordinary facts, the proof of a law which the animal in its healthy state exemplifies at every moment. Let us consider in the series of animals the relative perfection of each organ, and it will be seen at once, that where any one of them is excellent, the others are less perfect. The eagle, which has a very piercing sight, has but a very obtuse sense of smell; in the dog, the latter sense is extremely fine, the former dull. The sense of hearing is particularly acute in the hare, that of touch in the bat; the cerebral action predominates in the monkey, and vigour of motion in the feræ.

Every species then possesses some particular division of its animal life, in a degree of excellence superior to that of the others. Not a single instance will be found, where the perfection of one organ does not appear to be acquired at the expense of the others. Man in general, abstraction being made of every other consideration, has the ear particularly good, and in the natural order of things, this must be so; because his speech, which exercises the ear incessantly, is for this organ a permanent cause of activity, and therefore of perfection. And not only in the animal life is this law remarkable; but it appears to have place also, in all the phenomena of the organic life. The morbid affection of one of the kidneys, of one of the parotid glands, will double the secretion of the other.

Let us now examine what happens in the process of digestion. Each system at such time is the seat of an exaltation of the vital powers. Immediately after the entry of the aliments into the stomach, the action of all the gastric viscera is augmented, the powers of life are concentrated about the epigastrium, and abandon the organs of the external life; from thence arise, as authors have observed, the lassitude, the inaptitude of the senses to the reception of external impressions, the tendency of the individual to sleep, and the cold which is so frequently felt in the integuments.

The gastric digestion being completed, the vascular succeeds, and the chyle is introduced into the circulatory torrent, for the purpose of undergoing the influence of this system, and that of respiration; accordingly the blood-vessels and lungs become in their turn, the focus of an increased action, the pulse rises, and the movements of the thorax are precipitated.*

It is then the glandular, then the nutrive system which enjoy a marked superiority in the state of their vital powers. Lastly, when these powers have been successively developed, over all the system, they return to the organs of the animal life, the senses resume their activity,

* We know that at a certain period of digestion the pulse rises and respiration is accelerated; we know it, I say, but we do not know the immediate causes of the phenomenon. Is it a reason, in fact, because a little chyle enters the lacteal vessels that the heart should accelerate the course of the blood in a system of vessels entirely distinct from these? Because afterwards this chyle, mixed in a small proportion with the venous blood, goes with it through the lungs, is it a reason that the motions of the lungs should be accelerated? Undoubtedly not; besides, the acceleration is not successive in these two functions, as Bichat seems to imply. The one is the necessary and immediate consequence of the other. But why does the action of the heart increase in this second period of digestion? We cannot tell; nor do we know why it diminishes in the first; for to think of explaining it by saying that the vital forces are then concentrated at the epigastric region, is a mere illusion; it is only changing the expression of the phenomenon, and clothing it in a hypothetical form.

the functions of the brain their energy, the muscles their vigour. Whoever reflects upon what he has experienced after a somewhat copious repast, will be easily convinced of the truth of these remarks.

In this way, the whole of the functions represent a species of circle, of which the one half belongs to the organic, the other to the animal life, the vital powers seem successively to traverse these two halves. When they are found in one half, the other is proportionably deprived of them, nearly in the same manner as every thing appears to languish and be reanimated in the two portions of the globe, accordingly as the sun refuses, or sheds down his beneficent influence.

Should any farther proof be required of this inequality of distribution with regard to the vital powers, we may find it in the process of nutrition. This process has always an excess of action in some one of the organs, which at such time may be said to live more than the others do. In the fœtus, the brain and the nerves, the inferior members after birth, and at the age of puberty, the genital parts and breast appear to grow at the expense of the others.

From such a variety of considerations, we may establish the following to be a fundamental law of the distribution of the vital powers, namely, that when they increase in one part, they decrease in the rest of the living œconomy, that the sum of them can never be augmented, and that they only transfer themselves successively from one organ to another. By the help of these general data, it is easy to perceive why we cannot at the same time attain to perfection in the various parts of our animal life, why we cannot at the same time excel in all the sciences.

Universality of knowledge in the same individual is a chimera; it is repugnant to the laws of our organization, and if history afford us some few instances of extraordinary men, who have thrown an equal light upon many of the sciences, such instances are but so many exceptions to the common laws of nature; for who are we, that we should venture on the pursuit of many things at once, and hope to attain in all of them a perfection, which for the most part, even when we have but a single object in view, escapes us?

Were we capable of following at once a number of occupations, such occupations would be those which have the greatest analogy among themselves with respect to the organs which they bring into exercise: and by restraining ourselves in this way within a narrow circle, we may, indeed, with a greater degree of facility excel in many parts; but even here the great secret of being superior in any one of them, is that of possessing but a mediocrity in the others.

Let us take, for example, the sciences, which bring into action the functions of the brain. We have seen that these functions relate especially to the memory, which presides over nomenclature; to the imagination, under the empire of which, is poetry; to the attention, which is chiefly excited by the details of calculation; and to the judgment, whose dominion embraces the whole of the sciences of reasoning. Now it is manifest from daily observation, that not one of these different operations of the mind is to be developed but at the expense of the others.

The habits of reciting the beauties of Corneille or Racine, we might naturally suppose would enlarge the mind of the actor; what can be the reason that from such habit he does not acquire an energy of conception beyond that of the vulgar? The reason depends in part, no doubt, upon the natural disposition of the man, but at the same time may be deduced from the greater efforts of memory, and the faculty of imitation, which such a person is obliged to exert: for the purpose of enriching these, the other parts of the brain are in a manner plundered.

Accordingly, when I perceive an individual, desirous at the same time of excelling by address of hand, in the operations of surgery, by depth of judgment in the practice of medicine, by extent of memory in botany, and by force of attention in metaphysical contemplation, methinks I see a physician, who, for healing a disease, for the purpose of expelling, according to the old expression, the morbific humour, at the same time undertakes to augment the whole of the secretions by the simultaneous use of sialagogues, diuretics, sudorifics, emmenagogues, &c. &c.

But would not the slightest acquaintance with the laws of the economy, suffice for hinting to such physician, that one gland pours forth a greater quantity of fluid, only because the others secrete a less? Should he not know that such a variety of medicines can operate in no decided way, and that to exact too much of nature, is frequently the means of obtaining nothing? The same may be asked of the individual who is desirous of simultaneous perfection, both in the bodily and mental exercises, who should pretend to double or triple his relative life, when nature has willed that he should only have the power of detaching from some few of his organs, some few degrees of force, which may be added to one or more of his other organs, and by no means that of increasing the sum of these powers.

Do we wish that any one organ in particular shall attain to perfection, we must condemn the others to inaction. We castrate men to change their voices; it is astonishing that the barbarous idea of depriving them of sight has not been found out also for the purpose of rendering them musicians, since it is well known how acute the sense of hearing is in the blind. The child, who should be destined to music, ceteris paribus, would make a much more rapid progress, were his ears to be assailed by harmonious sounds only, and every thing removed which might be capable of exercising his other senses.

It is a truth, then, that our superiority in such or such an art and science, may almost always be measured by our inferiority in other respects; and that this general maxim which the greater number of the ancient philosophers have insisted on, but which many of our modern ones would willingly overturn, has for its foundation one of the great laws of the animal economy, and will ever be as immutable as the base on which it rests.

VI. *Of the education of the animal life as to duration.*

The education of the organs of the animal life, is prolonged for a time which we cannot determine, as it is influenced by such a variety of circumstances; but the peculiarity of this education consists in its being the business of each age, to bring to perfection certain organs in particular.

In childhood, the senses more especially are educated; every thing seems to relate to the development of their functions. Environed with bodies which are new to him, the little individual seeks to know them all; he maintains in a sort of perpetual expectation those organs by which his connexions with what is near him are established, and undoubtedly his sensibility is excessively developed. His nervous compared with his muscular system, is proportionally very great; accordingly for the dissection of the nerves, we always prefer the bodies of children.

With the education of the senses, the improvement of the functions of the brain which relate to sensation is necessarily connected. In proportion, then, as the sum of the sensations becomes enlarged, the memory and imagination begin to come into play. The age which follows infancy, is that of the education of those parts of the brain in which these faculties are seated.—It is then, that there have existed a sufficient number of antecedent sensations for the exercise of the memory, and for the discovery of the type of those illusory sensations which it is the business of the imagination to assemble. On the other hand, the little activity of the judgment at this epoch is much in favour of the energy of these two faculties; and then the revolution which puberty brings on, the taste which it develops, and the desires which it creates, contribute very much to extend the sphere of the latter of them.

When perception, memory, and the imagination have been perfected, when their education is finished, that of the judgment commences, or rather becomes more active, for the judgment begins to be exercised upon the very first materials, with which it is presented. At this epoch the functions of the senses, and partly those of the brain have nothing more to acquire, and all the powers of the individual, are concentrated upon the education of the judgment.

Hence it is manifest, that the first portion of the animal life, or that by means of which we are acted on from without, and reflect such action, has at each age a division, which is then particularly unfolded. The first age is that of the education of the senses, the second that of the enlargement of the imagination, the third that of the development of the judgment.

We should never then prescribe the study of the sciences, which exact the exercise of the judgment, at an age when the senses are especially in action; but follow in our artificial methods of education, the same laws which preside over the natural education of the organs. The child should be applied to music and design; the adolescent, to the sciences of nomenclature, and the belles lettres; the adult, to the exacter sciences, where facts are connected by a process of reasoning. The study of logic and the mathematics, terminated our ancient plan of education; it was one advantage at least among its numerous imperfections.

As to the second portion of the animal life, or that by means of which the animal reacts upon external bodies, the state of infancy is characterized by the number, the frequency, and feebleness of its motions; adult age by their vigour; and adolescence by a mixture of the two. The voice, however, does not appear to follow these proportions, but is subject to an influence which proceeds especially from the organs of generation.

I shall not dwell upon the different modifications, which with respect to the animal life are derived from sex, climate, and season. So many have treated of these questions, that it would be difficult to add to what has been said upon them.

In speaking of the laws of education, as they affect the organs of the external life, I have supposed these organs to be in a state of complete integrity, and possessed of whatever is necessary to their perfection.—If they be feeble or delicate, if any defect of conformation exist in them, these laws will only be applicable more or less; for it is manifest that the habit of judging will not rectify the judgment, if the brain be badly constituted; and that the frequent exercise of the larynx and voluntary muscles, will never make up for the irregularity of action occasioned by irregularity of conformation.

CHAPTER IX.

OF THE ORIGIN AND DEVELOPMENT OF THE ORGANIC LIFE.

We have just now seen that the animal life, which is inactive in the fœtus, is developed after birth: we have also followed up the particular laws of its development. On the contrary, the organic life comes into action almost as soon as the fœtus is conceived; for as soon as the least organization is apparent, the little heart will be seen protruding its blood on all sides. The heart is the first formed part, the first in action: now, as all the organic phenomena depend upon it, we may readily conceive in what way the functions of the inward life are thrown into exercise.

I. *Of the mode of the organic life in the fœtus.*

Nevertheless, the organic life of the fœtus, is not the same as that which the adult is destined to enjoy. Let us enquire into the reason of this difference.

We have said that the organic life is the result of two great orders of functions, of those namely of assimilation and decomposition, so as to form an habitual circle of creation and destruction. Now in the fœtus this circle is singularly contracted.

For in the first place, the functions of assimilation are much fewer in number; the molecules before they arrive within the organs which they are destined to create, are not submitted to so many actions; they penetrate the fœtus already elaborated by the digestion, circulation, and respiration of the mother. Instead of traversing the apparatus of the digestive organs, which at this age appear to be almost inactive, they enter at once into the system of the circulation; the road which they have travelled is less, it is not requisite that they should be presented to the influence of respiration; and accordingly the fœtus of the mammalia has in its preliminary organization a near analogy with that of the adult reptile, in which but a small part of the blood at its issuing from the heart, is sent into the vessels of the lungs.*

* I am persuaded that the still very obscure theory of the fœtus might be elucidated by that of animals who have a similar organization. For example, in the frog, in whom but little blood goes through the lungs, the heart is a simple organ, with a single auricle and ventricle; there is a communication or rather continuity between the two systems, venous and arterial, whilst in the mammalia, the vessels in which the red blood circulates do not communicate with those which carry the black blood, except it be by the capillaries.

In the fœtus, the foramen ovale and the ductus arteriosus also render very evidently the arteries and veins continuous; in the fœtus the heart is likewise a simple organ, not forming, notwithstanding its partitions, but one cavity whilst it is double after birth. The two kinds of blood mix at this period, as in reptiles. Now, I shall prove hereafter, that in the child who has breathed, this mixture would soon be fatal; that the black blood, circulating in the arteries, would very quickly produce asphyxia in the animal Whence arises then this difference? It cannot be studied in the fœtus; it is necessary perhaps to search for it in frogs, salamanders and other reptiles, which can, by their organization, be a long time deprived of air without dying, a phenomenon which approximates them to the mammalia while living in the womb of the mother. Till these very important researches are made, the history of respiration will be incomplete.

The molecules of nourishment in this way pass almost directly from the circulating torrent into the nutritive system. The general process of assimilation, then, is much less complicated than that of the following age.

On the other hand, those functions which habitually decompose the organs, which clear the system of substances already become injurious and foreign to its nature, are at this age but very inactive. Neither the pulmonary exhalation, nor sweating, nor transpiration have as yet commenced: the bile, urine, and saliva are but small in quantity, if compared with what they are destined at a future time to be, so that the portion of blood from which they are to be made in the adult, in the fœtus is almost entirely expended on the system of the nutritive organs.

The organic system of the fœtus, then, is remarkable—on the one hand, for the extreme promptitude of its assimilation, a promptitude depending on the very small number of the functions concurring to that end; and on the other, for the extreme inertia of its decomposition, an inertia depending on the little activity of the different functions, which are the agents of this great process.

It is easy from the foregoing considerations to account for the rapidity which characterizes the growth of the fœtus; a rapidity which is manifestly out of all proportion with that which takes place at any other age. Indeed, while every thing is in favour of the progression of the nutritive matter towards the parts where it is destined to be put down, every thing at the same time seems to oblige such matter to remain in the place where it has been deposited, the emunctories of the system being wanting.

To the great simplicity of assimilation in the fœtus, we may add the great activity of the organs which contribute to it an activity, which depends upon the more considerable sum of vital power which they then partake. All the powers of the economy, indeed, appear to be concentrated upon the system of the circulation and nutrition; the functions of digestion, respiration, secretion and exhalation, are exercised but obscurely.*

If we now observe that the organs of the animal life, which are condemned to a necessary inaction, are the seat at the same time of a very small portion only of vital power (the surplus of this being thrown upon the organic life) it will be easy to perceive, that almost the whole of the powers which are afterwards to be developed upon the two systems in general, will be then concentrated upon those which serve to nourish and compose the different parts of the fœtus, and that in consequence the functions which concur to the process of nutrition and growth, must at that age be the seat of an extreme energy.

II. *Development of the organic life after birth.*

Immediately after birth, the organic life of the child has a great addition made to it ; its extent is almost doubled, for not only are many of the functions which did not before exist at such time added, but those which existed previously are much enlarged. Now in this remarkable revolution of things, a law directly the contrary of that which presides over the animal life is observed ; for the organs of this life, whether they be newly brought into exercise, or simply receive an increase of action, need no education; they suddenly attain to a perfection, which those of the animal life do not acquire, otherwise than by

* This explanation is no doubt ingenious, but it is insufficient, since the causes which Bichat assigns for the rapidity of the growth of the fœtus cease entirely at the moment of birth, and yet the growth continues for a long time after to be as rapid.

long habitude. A rapid glance upon the development of this life, will be sufficient to convince us of the truth of the above observation.

At the instant of birth, digestion and respiration, with a great part of the exhalations and absorptions commence. Now after the first inspirations and expirations; after the elaboration in the stomach of the first milk, which is taken in by the infant, as soon as the exhalants of the lungs and the skin have once rejected some small portions of their respective fluids, the respiratory, the digestive and exhalant organs, have as perfect an action as they ever will have.

At the same time all the glands, which slept as it were, which poured forth but a very small quantity of fluid, are awakened from their torpor by the stimuli of the various substances which are applied to the mouths of their excretory ducts. The passage of the milk at the extremities of the stenonian and wartonian ducts, of the chyme at the end of the choledochus and the pancreatic duct, the contact of air with the orifice of the urethra, awaken into action the salivary glands, the pancreas, the liver, and the kidneys. The air in like manner upon the inner surface of the trachea and the nostrils, and the aliments upon that of the digestive passages, are the excitants which rouse these parts into action.*

* When two phenomena are seen to follow each other immediately, we are naturally led to consider one as the cause of the other. *Post hoc ergo propter hoc.* It is a form of reasoning which is very often abused. Food taken into the mouth touches the orifice of the salivary ducts, the fluid flows out, and it is then concluded that the salivary gland has been excited by the impression made on the extremity of its canal. At the moment of birth, the orifice of the urethra is exposed to the contact of the air, and soon the kidneys begin to secrete; then it is the impression of the air on the urethra that has produced their action. But is not this contact of the food in the one case, and of the

It is then also that begin the various excretions of the system: now if we examine well the different organs which concur to the above mentioned phenomena, we shall find that they require no sort of education.

I shall not inquire into the reason of this difference in the development of the two lives. I shall only observe that it is out of the power of any one of the inward organs, to acquire a marked degree of superiority over any other, for the same reason that they all of them attain, immediately upon entering into action, as great a perfection as at any time they are destined to possess.

Nevertheless there is nothing more common than the predominance of one system of the organic life over the other systems; this is sometimes the vascular, sometimes the pulmonary apparatus, at other times the organs of digestion, and the liver especially, have the greater degree of development, and decide on the particular temperament of the individual; but the cause of this sort of constitution depends on primitive organization, on the structure of the parts, on their conformation. Such superiority is by no means the effect of exercise or habit, for the fœtus and the child display the same phenomena, in as much reality though less apparently indeed, than adolescence, or manhood.

In the same way, the debility of any particular system of the internal functions, may depend either on original constitution, or on some accidental vice or disease, by

air in the other an accidental and purely accessory circumstance? Do we believe, that if by any cause the opening of the prepuce was entirely obliterated, the secretion of urine would be prevented? Do we not know that if instead of taking into the mouth savoury food, it is brought near to it, the saliva flows not less, or in vulgar language the mouth waters? There is however no contact, there is not any mechanical or chemical impression in the orifice of the salivary ducts.

which, while the others have remained untouched, its constitution may have been impaired.

Such then is the great difference of the two lives of the animal, with respect to inequality of perfection in the organs. In the animal life, the predominance or inferiority of one system, with relation to the others, depends almost entirely upon its activity or inertia, on its habitude of acting or not acting. In the organic life on the contrary, such states are immediately connected with the texture of the organs, and never with their education.

From hence also we have the reason why physical temperament, and moral character, are not susceptible of change from education, which so prodigiously modifies the actions of the animal life, for as we have seen, they both of them belong to the organic life.

The character is, if I may so express myself, the physiognomy of passions; temperament, that of the internal functions: now the one and the other being at all ages the same, having a direction which habitude and exercise can never alter, it is manifest that they must ever be withdrawn from the influence of education. The violence of the temperament may indeed be moderated, for the powers of the judgment, and reflection may be augmented, and the animal life strengthened in such way as to give it a capacity of resisting the impulses of the organic life; but to attempt an immediate alteration of the character, or of the passions, which are its habitual expressions, is an enterprise analogous to that of the physician, who should attempt to elevate or depress, (and that, for the entire life of the patient,) the ordinary contracting powers of the heart and arteries.

We should observe to such physician, that the circulation and respiration, are not under the dominion of the will; and that they cannot be modified excepting in passing into a state of disease. The same observation might be made to those, who imagine that the character, and consequently the passions may be modified.

CHAPTER X. —17—

OF THE NATURAL TERMINATION OF THE TWO LIVES.

We have just now seen, that the two lives commence at distant epochs; we have seen them developing themselves according to laws, which are exactly the reverse of each other. I shall now attempt to describe them, as they terminate; and this they do in a very different manner also, assuming characters at such time as distinct and separate, as those which they possess during the periods of their activity. In this place, I shall speak of natural death only; those deaths, which originate in accidental causes, will be the object of the second part of this work.

I. *In Natural Death the animal life is the first to cease.*

Natural death is remarkable for the following reason chiefly:—it terminates the animal life, a long time before it puts an end to the organic life.

He who dies in consequence of a very prolonged old age, dies in detail; his exterior functions are finished, one after the other; the senses are shut up successively; the ordinary causes of sensation pass over them, and do not affect them.

The sight grows dull and confused; it ceases at length to transmit the images of objects: this is the blindness of old age; sounds also, after a certain time, affect the ear confusedly; the organ at last becomes entirely insensible. The cutaneous covering of the body grows hard and dry; it is the seat of an obscure and imperfect touch. Besides which, the habitude of feeling has blunted the power of feeling; at the same time all the other organs which are dependent on the skin, grow weak and perish; the hair falls, it is deprived of the juices by which it was nourished: to continue our description, odours make but a feeble impression upon the nostrils.

The taste indeed is a little more kept up; but let it be remarked that this sense is connected with the organic as much as with the animal life, and is therefore necessary to the internal functions: In this way, when all agreeable sensations have fled the old man, when their absence has already broken in part the connexions, which attach him to the world, his taste remains with him still; it is the last thread to which is suspended the pleasure of existence.

In this way, isolated in the midst of nature, already deprived of the greater number of the functions of the sensitive organs, the old man is soon to suffer the loss of the common action of the brain, for it is manifest, that there can scarcely be any farther perception, for the very reason that there is nothing farther coming from the senses. Meanwhile, the imagination lessens and is soon annihilated.

The memory of present things is destroyed: the old man in an instant forgets what is told him, because his external senses enfeebled and already dead, as it were, in no wise confirm what is intimated to him by the mind alone. Ideas escape him when the images, which are traced by the senses, do not keep their hold. On the contrary, the remembrance of the past remains with him, that which the old man has formerly known, has been taught him or at least confirmed to him by his senses.*

He differs from the child in this respect; the child judges only from the sensations which he experiences, the old man from those, which he has experienced.

The result of the two states is the same, for the judgment is equally uncertain, whether founded exclusively upon actual or past sensation. Its accuracy depends upon the due comparison of the two. No one can be ignorant, that in the judgment which we form from visible objects, the actual impression would frequently deceive us, were we not to rectify the error by what we are enabled to recollect, and may we not observe that past sensations, in a short time grow confused, if the features of the picture, which they have left with us, be not retraced by new and analogous impressions?

The present then, and the past with regard to sensation, are equally necessary for the perfection of the judgment. If either the one or the other be wanting there cannot be any comparison made between the two, and in conse-

* If the old man preserves with difficulty the memory of the most recent events, whilst he often retraces with the greatest ease the recollection of the most distant ones, it is not because the first have been more faithfully transmitted to him by his senses, but because these events had produced a greater impression on him. This is so true, that failure of the memory is sometimes remarked in old people who have their senses in perfection. On the other hand, very imperfect sensations may produce a very lively impression. A connoisseur in painting, when his sight is very bad, experiences in seeing a beautiful picture, a hundred times more pleasure, than one who is indifferent to it, though he examines it with good eyes, and the connoisseur preserves the image of it long after the other has lost it. We do not perceive the recollection of things, unless there is some circumstance connected with them that makes a lively impression; but in the same event, this circumstance will not be the same in all individuals, and it is sometimes by the most trifling of all that a man fixes the fact in his memory.

quence there must be a want of precision in the judgment.

For these reasons, the first and the latter ages of man, are equally remarkable for imbecility. Old age is second infancy. The two periods of life resemble each other with regard to want of judgment; they differ only as to the cause of such defect.

The interruption of the functions of the brain of the old man, is a consequence of the almost entire annihilation of the sensitive system with him; in the same way does the weakness of the locomotive power, succeed almost inevitably to the inactivity of the brain. This organ in fact re-acts upon the muscles, in proportion only as the senses act upon it.

The movements of the old man are few and tardy; he changes with difficulty the attitude, into which he has thrown himself; seated near the fire, and concentrated within himself, a stranger to every thing without him, he passes his days there, deprived of desire, of passion, and sensation; speaking little because he is determined by nothing to break his silence, yet happy in feeling that he still exists, when almost every other sentiment is gone.

The rigidity of the muscles however, and the diminution of their contracting powers, is another cause of inactivity in the old man, and doubtless has its influence; but it is by no means the principal one, since the heart and the muscular fibres of the intestines, contract the same rigidity, and are deprived of their powers of moving, in a very different way from that, in which the voluntary muscles lose it. With the voluntary muscles, it is not so much the power as the excitant of the power which is lost. If it were possible to compose a man with the senses and brain of old age, and the muscles of youth, the voluntary motions of such man, would hardly be more developed for the reasons which I have given.

From the above it is easy to see that the external functions of the old man are extinguished by degrees, and that his animal life has almost entirely ceased, while his organic life is still in activity. Under this consideration, the state of the animal about to suffer a natural death, is nearly similar to that of the fœtus in utero, or of the vegetable which lives within itself only, and for which external nature is absolutely silent.

If we now recollect that sleep entrenches more than a third upon the duration of the animal life, if we add to this the total absence of such life for the first nine months of existence, and its almost entire inactivity during the latter period of existence, it will be easy to calculate the great disproportion of its duration, when compared with that of the organic life which is exercised uninterruptedly.

But wherefore when we have ceased to exist without, do we continue to exist within, since our sensations and above all, our powers of locomotion, are especially destined to place us in relation with those substances, which are to nourish us. Wherefore are those functions enfeebled in a greater disproportion than the internal functions, and why is there no exact relation in the times of their cessation.

I cannot entirely resolve this question. I shall only observe that society has an especial influence in creating this difference; for man in the midst of his fellow-creatures makes a very great use of his animal life; the springs of it are habitually more fatigued than those of his organic life, and worn away under the influence of society; the eye by artificial light, the ear by sounds too frequently repeated, and above all by those of speech, which are wanting to other animals;* the smell in like manner is debilitated by factitious odours, the taste by savours, which certainly are not natural, the touch and the tact by constant attrition of dress,† and the brain by too incessant thinking.

We live then externally with excess. We abuse our animal life; it is circumscribed by nature within limits which are too much enlarged by us for its duration; thus it cannot be surprising that it should cease so soon. In fact we have seen the vital powers divided into two orders, the one appertaining to this life, the other to the organic life. These two orders may be compared to two lights which burn at the same time, and which have only a determined quantity of materials for aliment. In which case, if the one be agitated by a stronger wind than the other is, it must necessarily be the sooner extinguished.

Yet social influence notwithstanding is very advantageous to man. It gradually disengages him from those bonds which attach him to life, and renders the instant of death less terrible.

The idea of our last hour, is painful only because it puts an end to our animal life. The borders of the tomb are beset with terrors, which will all be found to originate in the thought of such privation.

* This failure of the senses appears in animals as well as man, and it may be observed in those whom we suffer to grow old among us. We often see dogs becoming blind and deaf; and these infirmities are perhaps more common in them than in man. But as these animals are rarely permitted to arrive at extreme old age, we have not often an opportunity of observing them.

† By defending the skin from the shock of external bodies, and by preserving it from the variation of temperature, dress very certainly preserves its sensibility, and far from impairing the sense of touch, as Bichat maintains, it acts as a circumstance favourable to its preservation.

It is not the pain of death, which we fear; how many dying men are there for whom the gift of existence would be precious, though purchased at the expense of an uninterrupted series of suffering! If we look at the animal which lives but little externally, he by no means trembles at beholding the instant of his death.*

Were it possible to suppose a man, who in dying should lose his internal functions only, such man would look upon his death with an indifferent eye, because he would feel that the blessings of existence, are attached to the powers of feeling the influence of nature and society.

If the animal life then be terminated gradually, if each of the bonds by which we are capable of the pleasures of living, be broken by little and little, such pleasures will escape us imperceptibly, and the old man will have forgotten the value of life, when it is about to be taken from him; such destruction will resemble that of the vegetable only.

II. *The Organic Life in natural death does not terminate as it does in accidental death.*

The organic life remains with the old man after the almost total loss of his animal life, and terminates in a very different manner from that which is exemplified in the case of violent and sudden death. The latter has two periods, the first of which is marked by the sudden cessation of respiration and the circulation, the second

* The animal no doubt does not tremble at the moment of death; for he does not see it. His present sensation is every thing to him. If he suffers at the approach of death, he shows it by the usual signs; but it is only the present pain that he expresses, he sees nothing beyond. The child is in this respect, in the same situation as the animal.

by the slow and gradual extinction of the other organic functions.

The parietes of the stomach, for instance, continue to act upon the aliment which may be found there, the juices of the stomach continue to dissolve it. The experiments of the English and Italian physicians upon absorption, (experiments the whole of which I have repeated) have proved that this function not unfrequently remains in a state of activity, after the general death of the body, and if not as long as some have supposed, at least for a very considerable interval. Discharges of urine and feces are often observed to take place many hours after sudden death.

The process of nutrition also continues to be manifest in the hair and in the nails; the same would doubtless be the case in all the other parts, as well as in the secretions, could we observe the insensible movements of which their functions are the result. The heart of the frog being taken away, the capillary circulation may still be seen under the influence of the tonic powers. The body is very slow also in losing its animal heat.*

* In order to ascertain the cause of the differences in the cooling of the body after the various kinds of death, it is necessary to examine what general conditions can have an influence in the cooling of a body left to itself. Of these there are three principal ones.

Under the same external circumstances, a body will cool so much the slower. 1st. As its temperature at the beginning of the experiment, shall be higher in relation to that of surrounding bodies; 2d. As its surface shall be less in relation to its size; 3d. And as its exterior parts shall be less perfect conductors of heat.

In order to see how the first condition is modified in different cases, it is necessary to recollect what is the source of animal heat. The blood is warmed in passing through the lungs in consequence of the chemical phenomena of respiration; and as from the lungs it is carried to all parts of the body, it yields to the different organs a portion of the heat which it has received. Hence the general temperature of the

I might augment the above observations with a number of others, which would go to prove the same assertions; on

body will be higher in proportion to the temperature of the blood, to the frequency with which this fluid is renewed in the organs and to the quantity of it that is brought to them, at each pulsation.

Now in diseases of long duration, the volume of blood is considerably diminished, the activity of the heart is lessened, and respiration is performed in an imperfect manner. Thus the body of the patient who sinks under these circumstances has less heat to lose than that of the man who dies suddenly, when all these functions were performed in perfection.

Let us pass now to the second condition. The cooling, as we have said, takes place so much the quicker as the surface of the body is the more extended in proportion to its size; now, in the emaciation which accompanies almost all diseases that are protracted, the size decreases much more rapidly than the surface. Thus then, when even at the moment of death the general temperature of the body may be as high as in a state of health, the cooling would however take place more quickly.

It remains for us now only to examine under what circumstances the third condition is fulfilled in the most advantageous manner. When an individual in full health dies, the sub-cutaneous cellular texture usually contains a greater or less quantity of fat. Now we know that it is one of the characters of all fat substances to be very bad conductors of heat. Hence then a third reason which should render cooling more slow after sudden deaths. Sometimes after a disease, this last condition is fulfilled in another manner. In certain derangements of the circulation, the cellular texture is filled with serum; and as all aqueous fluids are bad conductors of caloric, though the temperature of the body may not be very high at the moment of death, the heat is yet preserved for a long time.

To the different causes which we have just mentioned, there is sometimes added another which is peculiar to one kind of sudden death. It is observed that in the midst of the same external circumstances, the blood does not always cool with the same quickness, and that in proportion as its coagulation is slower, its heat is longer preserved. Now, it is a well known fact, that when death is the result of asphyxia, the vessels are found full of fluid blood; this is also a reason which contributes to explain the slowness of the cooling. And it should be remarked, that asphyxia is one of the most frequent causes of sudden death either accidental or voluntary.

the contrary, in the death which is the effect of old age, the whole of the functions cease, because they have each of them been successively extinguished. The vital powers abandon each organ by degrees, digestion languishes, the secretions and the absorptions are finished, the capillary secretions become embarrassed; lastly, the general circulation is suppressed. The heart is the ultimum moriens.

Such, then, is the great difference which distinguishes the death of the old man, from that which is the effect of a sudden blow. In the one, the powers of life begin to be extinguished in all the parts, and cease at the heart; the body dies from the circumference towards the centre: in the other, life becomes extinct at the heart, and afterwards in the parts. The phenomena of death are seen extending themselves from the centre to the circumference.

BICHAT ON LIFE AND DEATH.

PART THE SECOND.

CHAPTER I.

GENERAL CONSIDERATIONS ON DEATH.

In the first part of this work, I have explained the two great divisions of life, together with the remarkable differences, which distinguish the animal existing without, from the animal existing within. I have discussed the characters which are exclusively proper to the two lives, and the particular laws, according to which they both of them commence, are developed and end in the natural order.

In this second part I shall inquire in what way they accidentally finish, in what way their course is prematurely arrested.

The influence of society suffers us but rarely to live out the period which was intended us by nature ; while almost every other animal attains his natural end, such end in the human species is become a sort of phenomenon. The different kinds then of accidental death, should engage the particular attention of the physician and physiolgist. Now this sort of death may happen in two ways : sometimes it is ther esult of great disturbance excited in the economy ; and sometimes it is the effect of disease.

In general it is easy enough to discover, according to what laws the functions are terminated in consequence of any violent or sudden attack ; of apoplexy, for instance, great hemorrhagy, concussion of the brain, or asphyxia ; because in such cases the organs of the body, excepting that which is immediately affected, are not the seat of any peculiar lesion, and cease to act from causes diametrically the contrary of those, which according to the common course of things maintain them in action. Now as these causes are partly known, their contraries may be inferred ; besides, we are capable of imitating these sorts of death upon animals, and consequently of analyzing, experimentally, their different phenomena.

On the other hand it is seldom in our power to produce artificially in the bodies of animals the diseases of the human species. Were we even possessed of such power, we should gain but little knowledge from it : the laws of life in fact are so changed, so modified, so altered in their very nature, by the various morbid affections to which the parts are subject, that but very seldom can we depart from the known phenomena of the living animal, when we undertake to inquire into those which it exhibits in its dying moments. For such inquiries it would be necessary to know what is that intermediate state between health and death, in which the functions experience so remarkable a change ; a change, which has such infinite varieties, and produces such innumerable sorts of disease. But, where shall we find the physician, who will assert that from the actual data of his art, he understands in such intermediate state, the profoundly hidden operations of nature ?

In these researches then, we shall occupy ourselves more especially on those sorts of death which I first enumerated. Those, which have been mentioned in the preceding paragraph will engage us only now and then : besides, at my age I cannot be supposed to have acquired a sufficient degree of medical knowledge to treat of them with advantage.

The first remark, which the observation of the different kinds of sudden death suggests, is, that in all of them the organic life to a certain point may subsist, the animal life being extinct; but that the latter is entirely dependent, and lasts not for a moment after the interruption of the former. The individual, who is struck with apoplexy may live internally for many days after the stroke, externally he is dead. In this case death commences with the animal life: if on the contrary it exerts its influence in the first place upon any of the essential organic functions—as on the circulation in wounds or on respiration in the asphyxiæ—the animal life is gone at once, together with the sensible actions of the organic life.

The red and warm-blooded animal, loses his external life at the moment when he ceases to exist internally, the cessation of the phenomena of his organic life is a sure index of his general death; indeed the reality of death can be pronounced only from such datum; the interruption of the external phenomena of life is in almost every instance fallacious.

On what depends this difference of the manner in which the two lives accidentally end? It is owing to the mode of that influence, which they exercise the one over the other, to the kind of bond, by which they are connected.

This mode of influence, this bond, appears to exist between the brain on the part of the animal life and the lungs, or heart on the part of the organic life. The action of one of these three organs is essentially necessary to that of the two others; and as they constitute the three centres, in which are terminated all the secondary phenomena of the two lives, whenever they cease to act, the phenomena which depend upon them must cease also, and general death ensue.

Physiologists have been at all times acquainted with the importance of this triple focus; and have given the name of vital to all those functions, which have their seat in it. Under the point of view which at present engages our attention their ideas on this head are well worthy of notice, for every species of sudden death begins by the interruption of the circulation, the respiration, or action of the brain. In the first place, one of the three functions ceases, then the others successively; so that to expose with precision the phenomena of sudden death, we must consider them as they take place in the three principal organs, which we have mentioned.

We shall first inquire into those deaths, which begin at the heart, and afterwards into those, which begin in the lungs and in the brain. I shall explain in what way, when one of these organs is affected, the others die; and then demonstrate by what sort of mechanism the death of the various other parts of the body ensuses. Lastly I shall determine from the principles, which I shall then have laid down, the nature of the different species of disease, which are peculiar to the heart, the lungs, and the brain.

CHAPTER II.

OF THE INFLUENCE OF THE DEATH OF THE HEART, OVER THAT OF THE BRAIN.

I SHALL evidently have determined what is the mode of this influence, should I be enabled to establish in what way the action of the heart is necessary to that of the brain; for in this instance the cause of death will be no other than the privation of the cause of life. Now the heart can only act upon the brain in two ways; by the nerves, or the vessels which serve as their connecting medium. In fact these two organs have no other means of communication.

It is evident that the nerves cannot be the agents of such actions; it is the province of the brain to act by means of the nerves. The different parts of the body never influence the brain by such means, excepting in the sympathies. If a bundle of nerves belonging to the voluntary muscles be tied, the muscles indeed will cease to act, but nothing will be changed in the cerebral mass.*

I have ascertained by many experiments that the phenomena of galvanism, which are propagated so energetically from the brain towards the organs, which descend, if I may so express myself, along the nerve, will hardly ascend in a contrary direction. Apply the apparatus to a nerve of the loins and the muscles of the upper limbs, and when the communication is made, there will be scarcely any contraction; but on the establishment of a communication between the same nerve and the lower limbs, a violent convulsive motion will instantly be occasioned. I have even observed, on placing two metallic plates, the one under the lumbar nerves, and the other under the upper limbs, that the communication of the two plates by means of a third metal, will cause a con-

* It is not true that a ligature on a nerve produces its effects only on the part to which this nerve is distributed; the brain is also affected; for, without this, how can be explained the pain that is felt, and the excitement, which is often sufficiently powerful to produce convulsions, and sometimes even death.

traction of the lower limbs, while the upper limbs remain inactive, or move but feeble.*

These experiments are particularly applicable to the relation of the heart with the brain; for not only is it true that the section, ligature or compression of the cardiac nerves are of little effect with regard to the functions of the latter, but it is true also, as we shall presently see, that they do not directly modify the movements of the former. We may conclude that the vessels are the exclusive agents of the influence of the heart upon the brain.

The vessels, as every one knows, are of two sorts—venous or arterial—they carry black or red blood, the latter answer to the left side, the former to the right side of the heart. Now their functions being very different, the action of one of the portions of this organ on the brain, can never be the same as that of the other portion. We shall inquire in what way they both of them act upon it.

In naming these two portions, I shall not make use of the expressions of right and left to distinguish them, but of those of the red-blooded and the black-blooded heart, for each of these portions of itself is an isolated organ, distinct from that to which it is applied, and in the adult especially so. In fact there are two hearts, the one arterial, the other venous, notwithstanding which, we can hardly employ these adjectives for the purpose of designating them, since they both alike possess their arterial and venous appendages. On the other hand, they are neither of them situated exactly to the right or to the left, are

* The facts related here by Bichat are not conformable to those, which, the philosophers and physiologists have observed who have been more particularly engaged with this kind of experiments. Besides the consequences which he has drawn from them are not accurate, and he seems to be ignorant what course the galvanic fluid in this case takes.

neither of them exactly forwards or backwards. Besides which these latter denominations would not apply to animals.

I. *In what way does the cessation of the functions of the red-blooded heart interrupt the functions of the brain?*

The red-blooded ventricle and auricle, exert their influence upon the brain by means of the fluid which they send thither through the carotid and vertebral arteries. This fluid may excite the cerebral organ in two ways. 1st. By the movement, with which it is directed. 2nd. By the nature of its colouring principle.

It is easy to prove that the movement of the blood is necessary to the life of the brain. Expose the brain of an animal in part, and tie the carotids. In such case the cerebral movement will be sometimes weakened, and then the animal will be stupified, at other times the vertebral arteries will exactly supply the place of the carotids, and then there will be nothing deranged in the principal functions of the brain; for there is always a relation existing between the alternate rise and fall of the cerebral mass, and the energy of life which it displays.*

In general, the obliteration of the carotids is never suddenly mortal. Animals will live without them, at least for a certain time. I have kept dogs in this state

* If there is always a relation between the vital energy of the brain and its alternate motions, it is because there is a constant relation between these motions and the entrance of the blood into the organ. Thus then, instead of considering this shock as the exciting cause of the brain is it not more natural to see in it only an effect purely accidental of the arrival of the arterial blood, which every thing proves to be the real excitant?

for several days and have afterwards made use of them for other experiments: two however died in the course of six hours, after the application of the ligatures.

After having made the above experiments which go very far to the establishment of the principle which I am labouring to prove, let a piece of the cranium be taken from another animal and tie the vertebral and carotid arteries. The movement of the brain will then be entirely interrupted and the animal immediately die.

The impulse, which proceeds then from the influx of the blood into the brain, is a condition essential to the functions of this organ, but other proofs may be adduced, for the establishment of the truth of this assertion.

1st. There are a number of compressions, which can only act by preventing the brain from being duly affected by such impulse. A collection of pus, or blood, will often put a stop to all the functions, which relate to the perception, memory, and voluntary motions of the individual. Let such compression be removed and his sensibility will immediately re-appear. In such case, it is manifest that the brain was not disorganized, but only compressed, and in a state incapable of being excited by the heart.*

I do not think it necessary on this subject to cite cases. All authors, who have treated of wounds of the head, are full of them. I shall content myself with remarking, that the same effect may be artificially produced in our experiments upon animals, and that accordingly as the brain is compressed or free, the creature will be insensi-

* As we know absolutely nothing of the manner in which the intellectual phenomena are produced in the brain, we cannot say whether compression prevents their development by stopping the motions with which the brain is habitually agitated, or by preventing the entrance of the arterial blood, or finally in some other way that we do not suspect.

ble, or the contrary. According to the degree of the compression, will be the degree of the stupor.

2dly. There are reptiles, in the brain of which no motion whatever is occasioned by the heart. The frog is of this species. On raising the upper portion of the cranium, and exposing the brain, there cannot be perceived the slightest motion. Now in this species, and that of the salamander, the influx of blood may be cut off from the cerebral organ without occasioning the immediate death of the animal. The voluntary muscles for instance continue to act; the eyes to exhibit a lively appearance, the tact also of the creature is manifest for some time after the heart has been taken away, or the double branch which proceeds from the single ventricle of these animals has been tied.* I have frequently repeated these experiments, and have constantly found the effect the same.

3rd. It is a general observation, that those animals which have a long neck, and in which the heart for that very reason is not so capable of exerting a lively influence over the brain, have a more limited intellect, and the cerebral functions less marked. On the contrary a very short neck, and the approximation of the heart to the brain very generally are found to coincide with the latter. Similar phenomena are sometimes observed in men. They who have the neck particularly long are dull, they who have it short, for the most part intelligent and lively.

* The organization of these animals differs too much from that of man to enable us to draw conclusions from one to the other, especially in what concerns the functions of the nervous system. There is an experiment of M Dumeril in which a salamander lived a long time after the amputation of the head, till the formation of a perfect cicatrix in the neck, which intercepted the passage of air to the lungs.

From these many facts we may confidently assert, that one of the means, by which the heart maintains the brain in action, consists in the habitual movement, which it impresses on it.

But this movement is essentially different from that which in the other viscera, such as the liver, or spleen, is derived from the same cause. In these it is little manifest, in the brain it is very apparent; the reason is evident; the large arterial trunks of the brain, are situated at its base, between the brain and its bony parietes; in consequence of which, at each diastole, the vessels experience a resistance from the bone, which is communicated immediately to the cerebral mass. At such time the brain is really lifted, just in the same way as we see a tumour lifted by the arteries which creep along the bones beneath it; and instances of this are frequent. So apparent indeed is the motion of tumours when they are situated over the carotid, as it lies upon the vertebral column, or over the femoral artery, immediately after its passage under the crural arch, as often to occasion doubts with respect to their nature.

But no other organ is enclosed within a bony cavity; the motion of the arteries every where else, is lost in the surrounding cellular substance, or soft parts. Such motion, then, is unessential to the functions of the liver, the kidney, and other analogous viscera.

The integrity of the functions of the brain, is not only dependent on the mere motion, but on the sum also of the motion communicated. It is equally impaired by too much, or by too little motion. Of this assertion the following experiments are proofs.

1st. Inject water by the carotid of a dog; the presence of this fluid in the brain is not pernicious, and the animal will live very well, when the injection has been skilfully made. But if it be pushed with violence, the cerebral action will immediately be troubled, and often cannot be restored.* In every experiment, there will be found to exist a relation between the force of the impulse and the state of the brain; if the pressure be but a little augmented, its effects will be instantly seen in the agitation of the countenance of the creature; if relaxed, a corresponding calm will succeed; if increased to the highest pitch, it will immediately occasion death.

2dly. If the brain be exposed, and an artery afterwards opened, so as to produce a considerable hemorrhage, the motion of the brain will be diminished in proportion as the afflux of the blood to it is diminished, and finally will cease entirely. Now, according to all these various degrees of diminution, which may be observed in the movements of the brain, will be the corresponding weakness of the cerebral influence as it is discoverable in the state of the eyes, the touch, and the voluntary motion of the animal.†

Hence it is easy to see, why a state of prostration and languor is always the consequence of great hemorrhage—

* Why are not the cerebral functions disturbed, when water is pushed slowly into the carotids? because there is then mixed with the blood of the artery too small a quantity of water at a time to enable this fluid to have a very evident action on the brain. But if this introduction of water into the mass of blood continues, whatever precaution may be taken, its effects soon show themselves. We have often, in our experiments, introduced a great quantity of water into the veins of an animal, and though much of it passed off by pulmonary transpiration, the arterial blood soon became very aqueous. Now, we have always observed, that in this case, the animals were struck with a kind of stupidity, which evidently indicated a want of action of the brain.

† It is not uncommon to see patients, who retain their intellectual faculties perfectly, when the motions of the heart are so feeble, that they certainly cannot produce, in the mass of brain, any sensible jar.

and from what has been said above we may conceive the reason, why the arterial system of the brain has been at first concentrated at its base, while the larger venous trunks are almost all of them situated on the convexity of its surface. The base of the brain is small and easily moved, the convexity large and little capable of transmitting motion, such as could be made upon it by vessels. Besides, it is at the lower part of the brain that exist its particular and essential forms. The lesions of these are mortal, and consequently their functions must be important. On the contrary, experiment and observation alike have proved, that very little derangement follows, from cutting or rending the substance of the upper part of this organ. Hence also we may see the reason, why its natural defences towards its base, are constituted in such way as to be almost impenetrable, and why at its upper surface, it is less protected. Now, where its life is indispensable, and its action absolutely necessary, it should naturally receive the first and undiminished impulse of its excitant. We may conclude, that the interruption of the action of the red-blooded heart is the occasion of interruption in the action of the brain by annihilating its movement.

But this movement is not the only means by which the influence of the heart is exerted on the brain; for if it were so, we might easily reanimate the enfeebled functions of the latter, by injecting it with water at the same time through both the carotids. If pushed with an equal force, the black blood and the red blood alike would be capable of keeping up its action; but this, as we shall presently see, is not the fact.

The heart, then, acts upon the brain by the nature of the fluid which it sends thither; but as the lungs are the focus, where the blood undergoes an alteration, we shall refer the examination of its influence upon the cephalic system, to the chapter in which we shall treat of the relation of this system, with that of the lungs.

II. *In what way does the cessation of the functions of the black-blooded heart interrupt the functions of the brain?*

It very rarely happens that general death commences by that of the venous auricle and ventricle. On the contrary, they are almost always the last in action, and when they cease to act, the brain, the lungs, and the red-blooded heart have already ceased to exhibit their respective phenomena. Nevertheless the contraction of these cavities may be annihilated, or rendered at least inefficacious with regard to the circulation, from the rupture of an aneurism or similar causes; in which case the brain becomes inactive and dies, as we have shewn it to do in the preceding section, from want of movement.

There is another kind of death of the brain depending on the interruption of the transmission of blood from the head to the heart, as when the jugulars are tied. The venous system, in consequence, is glutted and the brain compressed, from the continued afflux of the red blood into its arteries; but the phenomena of this sort of death are already sufficiently known.

In the present chapter it is my intention to examine a species of death, the principle of which by many physiologists has been placed in the heart, but which appears to me to affect the head only; I mean that death which may be occasioned by the injection of air into the veins.

It is generally known, that as soon as any quantity of this fluid is introduced into the vascular system, the movements of the heart are accelerated, that the creature is much agitated, cries with pain, is convulsed, and soon after deprived of its animal life, but lives organically for a certain time, and then invariably dies.* Now, what is the organ so readily affected by the contact of air? I affirm it to be the brain, and not the heart; and maintain that the circulation is annihilated, only because the cerebral actions have previously been so.

For, in the first place, in this kind of death, the heart continues to beat for some time after the cessation of the animal life, and consequently for some time after that of the action of the brain.†

Secondly, By injecting air into the brain through one of the carotids, I have caused the death of the creature just in the same way as when air is introduced into the

* A very considerable quantity of air can be forced into the veins of an animal, without causing its death, provided it be not pushed in suddenly. In all these cases, it is understood, that the quantity that can be thus introduced is in proportion to the size of the animal. I have before me at this moment the details of an experiment that I made on a horse at Alfort with M. Dupui, and in which, before the animal died, I was able, in thirty seven minutes, to inject quickly into the veins forty syringes full of air, and three syringes full into the carotid artery. (The capacity of the syringe was seventeen centilitres.) The animal died three minutes after the last injection. At the examination of the body, we found air in the azygos vein and in the thoracic duct, which contained much lymph, as well as the lymphatic vessels of the internal surface of the lungs. The heart was enormously distended with air mixed with a small quantity of blood.

† This is not correct, and death takes place, on the contrary, by the cessation of the motions of the heart. The right ventricle is filled with air; and this air, dilated by heat, so distends it, that it can no longer contract.

veins; excepting only with a previous palpitation of the heart.*

Thirdly, Morgagni has cited a number of cases of sudden death, the cause of which should appear, from his remarks, to be the repletion of the blood vessels of the brain by air, which had been developed there spontaneously, and which he says, by its rarefaction, compressed the origin of the nerves. I cannot suppose that such compression can be effected by the very small quantity of air, which, when injected into the carotid, is sufficient to occasion death; accordingly, I should doubt whether this compression were real in the cases adduced, but for this, they are not the less important. Whatever be the manner in which it kills, air is fatal whenever introduced into the brain, and this is the essential point. It is with the fact that we have to do and not the manner.†

* The disorders which are produced in this case do not at all resemble those which follow the entrance of air into the veins. If we push towards the brain, by the carotid artery, a small quantity of air, we see almost immediately signs of a strong cerebral congestion, spasmodic stiffness of the muscles, loss of sensibility, and of the action of the senses, and all the phenomena of a real apoplexy. Respiration and the circulation go on some time without any apparent alteration, but finally these two functions become embarrassed and the animal sinks. Every thing leads to the belief, that the alteration in the circulation of the brain depends here on the presence of rarefied air in the ultimate arterial ramifications.

When apoplexy is thus produced by the injection of air, if it be still forced into the artery, it breaks open violently a passage for itself, it tears the small vessels, and spreads in the parenchyma of the brain, which it makes emphysematous and crepitating under the finger. There finally returns a portion of it by the veins, which goes to the right cavities of the heart and which contributes to arrest the circulation.

† In the two examinations related by Morgagni, it appears that after a sudden death, there was found in the vessels of the brain an aeriform fluid, to the presence of which, for the want of another material cause,

Fourthly, As often as an animal is killed by the insufflation of air into one of its veins, I have ascertained that

was attributed the death of the individual; but there is no proof that this fluid might not be developed there after death. We shall now relate a more decided case of death occasioned by the presence of air in the blood vessels; but here there is no ground for doubt, because we know the circumstances of the introduction.

A locksmith, twenty three years of age, had had for five years a large tumour on the right shoulder and clavicle. His acute sufferings induced him to enter the hospital to have it removed.

It was necessary in the operation to remove the middle portion of the clavicle. Thus far the success was complete; but little blood was lost, the pulse was good and the breathing easy, when the patient suddenly cried out, *My blood is leaving my body! I am dead!* And at the same moment he became stiff, lost his consciousness, and was covered with a cold sweat. A singular and rather loud noise was heard in the interor of his chest. The surgeon thought that he had opened the pleura by removing a portion of the clavicle, and thus given access to the air and to the blood to the right side of the thorax. The fingers of an assistant were immediately thrust into the bottom of the wound, with the view of stopping the supposed opening in the pleura, and the surgeon endeavoured to introduce into the thorax the extremity of a sound of gum elastic. When he thought that he had succeeded, he drew with his mouth the air which he supposed to be effused in the pleura. He wished then to proceed to the dressing; and, in order to do this, he substituted, for the fingers of the pupil which were at the bottom of the wound, a sponge covered with wax; but the moment the sponge took the place of the fingers, the satme noise that was at first heard and which had ceased in an instant, was renewed with more force than before.

The syncope and cold sweat still continued. Water thrown into his face, made him give some signs of life; but he died a quarter of an hour after the appearance of the accident I have just described, and forty five minutes after the commencement of the operation.

The body was examined the next morning. They expected to find the right pleura open, much blood and air effused into its cavity and the lungs on that side collapsed. Nothing of the kind was found. The pleura was whole and there was no effusion in it. The lungs were as usual; but an opening of half an inch in extent was discovered in the external jugular vein, at the place where this vein opens into the subclavian. The cavities of the heart were large but contained no the whole of the red-blooded, as well as the black-blooded heart, is full of a frothy blood, mixed with air bubbles;

blood. Bubbles of air were observed in the vessels of the brain; the other vessels were not examined.

This fact was related to me the same day, by a student who was present. It was impossible for me not to refer the death in this instance to the entrance of air into the vessels. The opening in the vein, the noise that was heard, the suddenness of the death, the absence of blood in the cavities of the heart, the presence of air in the vessels of the brain, all sufficiently indicated it. I suspected that the entrance of air had been favoured by the state of tension of the parietes of the vein, or by their morbid alteration, which did not allow them to flatten by atmospheric pressure. I thought that this phenomenon might be produced at will on animals by placing them in the same physical circumstances. I introduced then into the jugular vein of a dog, a sound of gum elastic, and I directed it towards the heart. It was hardly there before I heard the air enter the vein, and the animal fell down in syncope, with the peculiar noise which manifests the presence of air in the heart. I immediately closed the sound to prevent the entrance of more air, and the animal gradually recovered, because the quantity of air introduced had not been in sufficient quantity to produce its death. I then opened the sound, and immediately the air rushed in towards the heart, and its entrance was followed by the same consequences; but, whether from not closing the sound soon enough, or from the entrance of a greater quantity of air, the animal died unexpectedly to me. In opening it, I found all the signs of death from the sudden entrance of air. The right ventricle was distended with air mixed with a little blood.

Sometimes, without any apparent alteration in the texture of the veins, its parietes do not flatten under atmospheric pressure; a simple puncture then is sufficient, as in bleeding, to admit the air into the vessels. Lieutaud relates two cases in which it appears that this took place, and several veterinary surgeons have assured me that they have heard, after bleeding in the jugular vein, a noise which indicates the entrance of air. Usually the quantity introduced is too inconsiderable to produce any evident effects. There has been communicated to me, however, a case observed by Mr. Bouley, the younger a veterinary surgeon in Paris, in which the entrance of air was followed by effects similar to those which we have related.

Mery had long since observed, that, in opening the abdomen of a dog, and that the carotids, and vessels of the head, contain a similar blood; such blood must act upon the brain, in the same manner as it does in the two sorts of apoplexy, of which we have just been making mention.

Fifthly, If air be pushed into one of the divisions of the vena portæ from the side of the liver, it oscillates in the greater trunks of that organ for a considerable length of time, and arrives but slowly at the heart.—In this instance I have observed, that the animal experiences, only after a certain interval, those affections which are sudden when the fluid is injected into the veins of the principal system.*

and puncturing the vena cava above the origin of the emulgents, as the vein become emptied of blood, it filled with air, which went to the right ventricle. Haller also observed that air entered into the veins of frogs and other cold-blooded animals in consequence of a wound of some large vessel. He has shown that it was from this source that was derived that which Redi, Caldesi, and Morgagni saw circulating in the vessels of these animals, since it is not observed, when the necessary precautions are taken to prevent its introduction.

Nysten has made a great number of experiments upon the injection of elastic fluids into the veins, and the results which he has obtained accord perfectly with those which we have observed. He is not satisfied with injecting atmospheric air, he has introduced in the same way a great number of other gases. He has remarked, that among the gases not deleterious he can introduce, without causing death, a much greater quantity if these gases are easily dissolved in the blood.

We cannot follow him in the detail of these experiments; we shall only relate a result relative to the colouring of the blood in the lungs. He has observed, that by injecting air into the vein, so slow as not to produce the death of the animal, the colouring of the arterial blood is rendered imperfect. He is satisfied, he says, that it is not owing to the embarrassment of the lungs. The injection of oxygen does not alter this colouring. The injection of azote completely prevents it; that of the oxide of carbon does not produce any change in it. I give these results from his work; I have not had occasion to verify them myself.

* When air is introduced into the vena portæ, there is not only no ill effect at the moment of injection, but there usually follows no

Sixthly, The rapidity with which, in certain experiments, the annihilation of the cerebral action succeeds to the insufflation of air into the veins, might almost persuade us that such phenomenon is occasioned, as it is in wounds of the heart and syncope;—but 1st. The most simple inspection is sufficient to shew us that the heart continues to act after the apparent death of the animal—2dly. As the motions of the heart are prodigiously accelerated by the contact of the foreign fluid, they push on the frothy blood with an extreme velocity, and hence we have the reason, why the brain in such case is so rapidly affected.

Seventhly, Were the cerebral action in this sort of death interrupted for want of movement from the heart, it would happen as it does in great hemorrhages of the aorta; that is to say, without violent convulsion. But here, on the contrary, the convulsion is extremely violent, immediately after the injection, and consequently,

apparent effect on the animal. It is not the same when air is injected into the veins of the general system, with so much care as not to produce instantaneous death by the dilatation of the heart. The effects do not then appear till a long time after the injection; but they are wholly different from the primary effects which we have described.

These consecutive symptoms from the entrance of air into the veins are, as Nysten has remarked, the result of an obstruction of the lungs produced by the accumulation of air in the last divisions of the pulmonary artery. The embarrassment in respiration often appears at the end of half a day, it becomes greater and greater, the bronchiæ are filled with a viscid fluid; and the animal usually dies on the third or fourth day. On examination of the body, no air is found in the heart or the vessels; but the lungs, instead of being pink-coloured, are greyish, tinged with brown, and loaded with frothy blood and mucus.

Boerhaave thought, that death which follows the injection of air into the veins was always owing, as it is in this case, to the presence of the air, which offers, in the small vessels, a mechanical obstacle to the passage of the venous blood.

announces the presence of an irritating substance on the brain.

We shall conclude, that in the accidental mixture of air with the blood of the venous system, it is the brain which dies the first, and that the death of the heart is the consequence of the death of the brain. I shall explain in another place, in what way this phenomenon is occasioned.

CHAPTER III.

OF THE INFLUENCE OF THE DEATH OF THE HEART OVER THAT OF THE LUNGS.

The lungs are the seat of two very different sorts of phenomena. The first, which are entirely mechanical, are relative to the rise and fall of the ribs and diaphragm, to the dilatation and contraction of the air vessels, and to the entry and exit of the air, which is the effect of these movements. The second, which are purely chemical, may be referred to the different alterations, which the air and blood experience.

These two sorts of phenomena have a mutual dependence on each other. Without the mechanical, the chemical changes could not be made; without the chemical changes, the blood would cease to become an excitant to the brain, in consequence of which that organ would no longer operate upon the diaphragm or intercostal muscles; the muscles themselves would then become inactive, and the motions of the thorax be annihilated. These phenomena, however, are put an end to in a different manner by the death of the heart, accordingly as it happens on one or the other side.

I. *In what manner are the actions of the lungs interrupted when the black-blooded heart ceases to act?*

The heart has certainly no influence over the mechanical functions of the lungs, but it contributes essentially to produce the chemical changes which are made there, by sending thither the fluid which is destined to undergo a change. When its functions then are interrupted as may happen from wounds or be occasioned by ligature, the chemical changes which should be made in the blood, are suddenly suppressed; though the air continue to enter into the lungs, from the dilatation and contraction of the chest.

Meanwhile there arrives nothing at the red-blooded heart, or* so little as to be insufficient for the production of the cerebral movements. The functions of the brain are consequently suspended, and of course the movements of the diaphragm and ribs.

II. *In what manner are the actions of the lungs interrupted, when those of the red-blooded heart are suspended.*

Whenever from wound, ligature, or aneurism, the functions of the red-blooded heart or aorta cease, the functions of the lungs are terminated in the following order:

* After the obliteration of the ductus arteriosus, the left ventricle receives no blood but what comes from the lungs; now, if the motions of the thorax continue, it is red blood; at least so long as the air is freely admitted into the bronchial tubes, and so long as the composition of this fluid is not changed by the mixture of foreign gases.

1st. There is no further impulse made upon the brain. 2dly, No further movement of that organ.* 3dly, No further action exercised upon the muscles. 4thly, No further contraction of the intercostals or diaphragm. 5thly, The mechanical functions of the lungs cease. 6thly, Their chemical functions cease.

In the former case, the chemical changes could not be made for want of blood. Here they cannot be made for want of air. Such is the difference in the death of the lungs, in consequence of that of the heart, according as the latter is affected. But as the circulation is very rapid, there cannot be but a very short interval between the interruption of the chemical and the mechanical functions of the lungs.

CHAPTER IV.

OF THE INFLUENCE OF THE DEATH OF THE HEART OVER THAT OF ALL THE ORGANS.

I SHALL divide this chapter, as the preceding one, into two sections. In the first I shall examine, how the death of the red-blooded heart, in the second how the death of the black-blooded heart, is the cause of the death of all the parts of the body.

I. *On the death of the red-blooded heart, and how that of the organs is occasioned by it.*

All the functions belong either to the animal, or to the organic life. Hence the difference of their classes. Now

* These two modifications should, after what we have said, be reduced to a single one, viz. want of excitement of the brain by the arterial blood.

the death of those of the first class, in consequence of lesions of the red-blooded auricle and ventricle, is caused in two ways, and first, because the brain in such case is rendered inert from want of impulse, and can neither have sensations, nor exercise an influence over the locomotive and vocal organs.

Accordingly, all this order of functions is stopped, as when the encephalic mass has experienced a violent concussion. It is in this way that a wound of the heart, or the bursting of an aneurism, annihilate all our relations with external objects.

So strict a connexion between the movement of the heart, and the functions of the animal life, is not observable in those animals in which the brain, in order to act, does not require the habitual stroke of the blood. Tear away the heart of a reptile, or tie its large vessels, and it will continue for a long time to move and have sensations.

Besides, supposing even that the action of the brain were not to be suspended from lesions of the red-blooded heart, the animal life would not, on that account, be the less put an end to; because to the exercise of the functions of this life, is attached as a necessary cause, the excitement of its organs by the afflux of blood into them: now this excitement, both here and every where else, depends upon two causes.—1st, On the movement impressed, and 2dly, On the nature of the blood. At present I shall only examine the first mode of influence; the latter will come under our consideration, when we speak of the lungs.

Habitual motion is necessary to all the parts of the body alike, is a condition essential to the functions of the muscles, the glands, the vessels, and the membranes, &c. But this movement, which is partly derived from the heart, is very different from that which is communicated by the blood to the brain.

The latter organ receives an impulse by which the whole of its mass is visibly raised, an impulse, in the intermission of which the whole of its mass subsides. On the contrary, the interior movement, by which its practicles are affected, is scarcely marked at all : and this depends upon the smallness and the delicacy of the vessels by which its substance is penetrated.

The contrary of this appearance is observed in the movement occasioned in the other organs by the influx of the blood into them : we see them neither rise nor subside; there is nothing like a general impulse made upon them, because, as I have said, such impulse is lost from the little resistance of the surrounding parts. On the contrary, they are penetrated by vessels of considerable magnitude, which create an intestine motion, oscillations, and impulses adapted to the actions of the tubes, lamellæ, or fibres, of which they are composed. This difference of movement may be easily conceived, by comparing the manner in which the brain on the one hand, and on the other the liver, the spleen, the muscles, or the kidneys receive their blood ; indeed it is requisite that the brain should be distinguished from the other organs, in the manner of receiving its impulses, because it is enclosed in a case of bone, and consequently abstracted from the thousand other causes of agitation, to which the other parts of the body are exposed.

For we may remark, that all the other organs have about them a number of agents, which are destined to supply the place of that general impulse, which is wanting to them on the part of the heart. In the breast, the intercostals and diaphragm are continually rising and falling ; the lungs and the heart are successively the seat of a dilatation and contraction. In the abdomen, there is an uninterrupted agitation produced, by the influence of respiration upon its muscular parietes ; an incessantly variable state of the stomach, intestines and bladder. Lastly, from the various contractions of the muscles, the limbs have a still more evident cause of movement.

Nevertheless, it is probable that every one of the organs, as well as the brain, has a general though obscure movement impressed upon it, from the pulsation of the arteries; and hence, perhaps, we have the reason, why the greater number of the viscera, receive the impulse of the red blood upon their concave surfaces, as may be seen in the kidneys, the liver, the spleen, and the intestines. By such disposition, the impulse of the heart is less divided.*

From what has now been said, we may add another reason to that which we have before given, for establishing in what way the functions of the animal life are interrupted from cessation of action in the red-blooded heart. We may now also begin to explain the same phenomenon in the organic life. The reason of such interruption in both the lives is the same. It is as follows :

1st. In the case of death affecting the red-blooded heart ; the intestine movement, which proceeds from the manner in which the arteries are distributed within the

* It should not be lost sight of, that all this discussion turns upon the application of a principle which is by no means proved : viz. that the different organs, in order to exercise their functions, require to be agitated by a partial or general motion. We have already made it appear, that as it respects the brain, this jarring of the whole mass, to which Bichat attributes so much importance, appears to be a circumstance purely accidental from the entrance of the arterial blood. The same may be said of the oscillatory motion produced in the other organs by the pulsation of the ultimate arterial ramifications.

substance of all the organs, both of the one and the other life, is suspended; hence there exists no farther cause of excitement for the organs: they must consequently die.—2dly. The causes of the more extensive and general movements of the organs are abstracted; for almost all these causes depend upon the brain. We respire and move, only while the brain is alive: but as the brain must be in a state of collapsus, as soon as it ceases to receive the impulse of its blood, its influence must be evidently annihilated.

Hence it follows, that the heart exercises over the different organs two modes of influence; the one direct and immediate, the other indirect, and made through the medium of the brain, so that the death of the organs in consequence of the death of the heart, is immediate or mediate.

We have sometimes examples of partial death, analogous to this sort of general death. Thus, when the circulation is impeded in a limb, and the red blood no longer distributed to its parts, such parts become at first insensible and paralytic, then gangrenous. The operation of aneurism furnishes us with too many instances of this phenomenon, which by ligature, may be produced also in the living animal. Undoubtedly the principal cause of death in these cases, is the want of that stimulus which it is the business of the particles of the red blood to create, in contradistinction to those of the black blood, but the absence of the intestine movement in question, is by no means a less real cause of such death.

As for the interruption of the nutritive process, it cannot be admitted as a cause of the symptoms which succeed after the obliteration of a large artery. The slow, the gradual, and insensible way, in which this function is performed, does not accord with the sudden and instantaneous production of those symptoms, especially as they affect the animal life; for this is annihilated in the limb at the very instant when the blood ceases to flow into it, just in the same way as it is, when by the section of its nerves, the influence of the brain is abstracted.*

Besides the preceding causes, which, when the heart is dead, suspend in general the whole of the animal and organic functions; there is another cause of death which especially affects the greater number of the latter, such as the processes of nutrition, exhalation, secretion, and therefore digestion, which is only performed by means of the secreted fluid. This cause of death to which I refer, consists in the necessary stop which is put to these different functions, in consequence of their no longer receiving the materials upon which they are exercised. Nevertheless, such term arrives by degrees only, because they receive the materials on which they act, from the capillary, and not from the general circulation. Now the capillary circulation, is only subject to the influence of the insensible contractile powers of the parts in which it is performed; and is exercised independently of the heart, as may be seen in the greater number of reptiles, where the heart may be taken away, and the blood be notwith-

* When the passage of the arterial blood to a muscle is stopped, a more or less complete numbness soon takes place; and this effect is too sudden to be attributed to the want of nutrition; and as certainly it is not owing to the want of agitation by the pulsations of the small arteries; for if, the artery is left free, and a ligature is applied upon the vein, the pulsations are increased rather than diminished and yet the numbness appears as quick as before.

When the muscle has been a long time without receiving blood, gangrene seizes upon it; and this can then be attributed, in great measure, to the want of nutrition. The diminution of the temperature, which necessarily takes place in an organ in which the blood is not renewed, must also contribute to this disorganization.

standing observed to oscillate for a long time afterwards in the minuter vessels.* It is manifest, then, that whatever quantity of blood is left in the capillary system at the period of the death of the heart, will for some time afterwards be sufficient to keep up the functions in question, and that such functions in consequence will only gradually cease.

The following is a general view of the manner in which the annihilation of all the functions succeeds to the interruption of those of the heart.

The animal life is terminated—1st, Because the organs of which it is composed, are no longer excited without, by the movement of the neighbouring parts, nor within, by the blood.—2dly, Because the brain, from want of excitement, can no longer be a cause of excitement.

The organic life is terminated—1st, Because, as in the animal life, there is a want of external and internal excitement for its different viscera.—2dly, Because there is a want of the materials on which its functions are particularly exercised.

There are a number of other considerations, however, besides those which we have mentioned, which prove the reality of the excitement of the organs, from the movement communicated to them by the blood, as well as the reality of the cause, which we have asserted to be that of their death, when such excitement ceases.

For, 1st.—The organs which are penetrated only by the serum of the blood, such as the hair, the nails, the tendons, and cartilages, enjoy a less degree of vitality,

* We know that the blood pushed into the arteries distends the parietes of these vessels, and brings into action their elasticity; now, after the heart has ceased to act, these parietes, by contracting, can impart, for some instants, an oscillatory motion to the fluid contained in their cavity.

and a less energetic action, than those in which the blood is made to circulate, either immediately by the heart, or by the insensible contractile powers of the parts themselves.

2dly.—When the white organs are inflamed, they receive an augmentation of life, a superabundance of sensibility, which frequently put them on a level in many respects with those organs, which in their natural state are endowed with the highest degrees of life and sensibility.

3dly.—Those organs which habitually receive the influx of the red blood, when inflamed, exhibit, in every instance, a local exaltation of the phenomena of life. In the two preceding instances, it is true, indeed, that the change of vital powers, precedes in point of time, the change which is made in the circulation; the organic sensibility of the part, has been augmented before the blood is carried thither in greater quantity; but afterwards it is the afflux of such increased quantity of blood, which keeps up the unnatural action which has been established. A determined quantity of blood in the ordinary state of the part, is necessary to the maintenance of that state; but when the part receives a double or triple increase of energy, its excitant also must be doubled or tripled; for in the exercise of the vital powers, there are always three things to be remarked; the power inherent in the organ; the excitant which is foreign to it; and the excitement which is the product of the two.

4thly.—It is doubtless, for this reason, that the organs to which the blood is habitually carried by the arteries, enjoy a degree of life, proportionate to the quantity of fluid by which they are injected. Such phenomenon may be observed in the glans penis, in the corpora cavernosa, in the nipple, in the skin of the face, and the actions of the brain, whenever the blood is directed with impetuosity towards them.

5thly.—The whole of the circulatory system, is thrown into greater action from the exaltation of the whole of the vital phenomena, just in the same way as the particular circulation of any part is augmented, when the particular phenomena of the life of that part are increased. The use of spirituous liquors, and spices to a certain quantity, is followed for a time by a general increase of energy in the powers of the system. The access of inflammatory fever will double and triple the intensity of life.

In these considerations I have only regarded the movement which is communicated to the organs by the blood. In another place I shall call the attention of the reader to that species of excitement, which is produced by the nature of the blood, by the contact of its component particles when in a state of oxydation or otherwise, with the different parts of the body. The reflections which I have offered, will be amply sufficient to convince us how much the blood, independently of the materials which it conveys with it, by its simple influx, is necessary to the activity of the organs, and consequently how much the cessation of the functions of the heart, must influence the death of the organs.

CHAPTER V.

OF THE INFLUENCE OF THE DEATH OF THE HEART AS TO THE PRODUCTION OF GENERAL DEATH.

Whenever the heart ceases to act, general death is produced in the following manner :—1st. For want of excitement the cerebral actions are annihilated, and consequently an end is immediately put to all sensation, locomotion, and utterance. Besides, for want of excitement on the part of the blood, the organs of these functions would cease to act, even supposing that the brain were to remain unaffected, and exert upon them its accustomed influence. Thus the whole of the animal life is suddenly suspended, and at the instant of the death of the heart, the individual is dead to what surrounds him.

The interruption of the organic life, which has commenced by the death of the heart, is produced at the same time by that of the lungs. The brain being dead, the mechanical functions of the lungs must cease: the chemical functions of the lungs must cease also, for want of the materials on which they are exerted: the latter are directly interrupted, the former through the medium of the brain.

After this the progress of death is gradual. The secretions, the exhalations, the nutritive actions are put an end to. The latter are first arrested in those organs which receive the more immediate impulse of the blood, because in these, such impulse is necessary to the performance of the functions. The paler organs are less dependent on the influence of the heart, and consequently must be less affected by the cessation of its action.*

In the successive termination of the latter phenomena of the internal life, the vital powers continue to subsist for some time after the loss of the functions: thus, the organic sensibility, and the sensible and insensible con-

* Life is so obscure in the tendons, ligaments, &c. that it is impossible to fix the moment when it ceases in these parts. How then has Bichat been able to compare the quickness of their death with that of the other organs? Upon what data has he been able to determine that it takes place more slowly?

tractilities survive the phenomena of digestion, secretion, and nutrition.*

The vital powers continue to subsist in the internal life, even when the corresponding powers of the animal life, have suddenly become extinct: the reason is plain: the power of perceiving and moving organically does not suppose the existence of a common centre; for the animal perceptions and motions, the action of the brain is requisite.

The phenomena of death are concatenated in the above order in all aneurismal ruptures, in all wounds of the heart or larger vessels, in all cases of polypi formed in the cardiac cavities,† of ligature artificially applied, of compression exercised on the parietes of the heart by humours, abscesses, &c. &c.

It is in this manner also that we die from sudden affections of the mind. The news of a very joyful, or a very melancholy event, the sight of a fearful object, of a detested enemy, of a successful rival, are all of them causes capable of producing death. Now in all these instances, it is the heart, which is the first to die, the heart, whose death successively produces that of all the other organs, the heart, on which the passion is exerted.

* The secretion of mucus, the growth of the nails, the beard and the hair often continue on the dead body long after the last traces of irritability have disappeared in the muscles of locomotion, in the fleshy coats of the intestines, &c.

† Since more care has been taken in examining the lesions of different organs in post mortem examinations, there is no longer found those fatty polypi, which were formerly considered as causes of death. It is probable that those yellowish concretions of albuminous matter which are found between the pillars of the auricle, and which seem to be fixed there, were mistaken for polypi. There is sometimes found in individuals formerly affected with the venereal disease, vegetations near the valves; but these productions are commonly too trifling to oppose the expulsion of the blood contained in the cavity.

And hence we are led to some considerations on syncope, an affection exemplifying in a less degree the same phenomena, which in a greater one, is offered us in cases of sudden death.

The causes of syncope are referred by Cullen to two general heads: Of these there is one set which according to him affect the brain, another set which affect the heart. Among the first, he places the more violent impulses on the mind, and various evacuations, but it is easy to prove, that the brain is only secondarily affected in syncope produced by passion, and that it is the heart, whose functions in all these cases are the first to be interrupted. The following considerations, if I am not mistaken, will leave but little doubt on this head.

1st.—I have proved, in speaking of the passions, that they never affect the brain in the first place; that the action of this organ, in consequence of their development, is only secondary, and that every thing relating to our moral affections has its seat exclusively in the organic life.

2dly.—The phenomena of syncope when produced by lively emotion, are similar in every respect to those of syncope, the effect of polypi or dropsy of the pericardium, but in the latter, the affection of the heart is the primary one, and should in consequence be the same in the former sort of syncope.

3dly.—At the moment when syncope takes place, we feel the attack at the heart, and not in the brain.

4thly.—In consequence of lively passions, which may have occasioned syncope, we find that the heart and not the brain becomes diseased, nothing is more common than organic affections of the former from sorrow, &c. The different sorts of madness, which are produced by the same cause, for the most part have their principal seat in some of the viscera of the epigastrium, and in such case, the irregularity of the cerebral action is the sympathetic effect of the profound affection of the internal organ.*

5thly.—I shall prove hereafter, that the cerebral system does not exert any direct influence over that of the circulation; that there is no reciprocity between the two, and that the changes of the first are not followed by similar changes in the second, however much the changes of the second may modify the first. Destroy all nervous communication between the brain and the heart, and the circulation will go on as usual; but if the vascular communications be intercepted, the cerebral action vanishes at once.

6thly.—Palpitations and other irregular movements of the heart are often the effect of the same causes, which

* The singular idea of placing the seat of madness in the viscera of the abdomen, arose at a period when a certain number of mystical ideas formed the basis of all physiology. The four sorts of humours performed in the human body (*microcosm*) a part as important as the four elements did in the whole universe (*macrocosm.*) The bile, the blood, the pituitary and atrabiliary fluids determined, by their predominance the different temperaments, and produced the different diseases. The atrabiliary humour was, as is well known, thought to be the cause of melancholy and mania; now this humour was said to be secreted by the supra-renal capsules, and the position of these organs no doubt gave the name of hypocondria, which is given to a certain degree of mental alienation.

After a great number of ages, the mysterious properties of numbers are almost entirely out of favour. We still speak of the four temperaments, but attach no importance to the four ages of man or to the four parts of the day. We recognize in the human body more than four kinds of fluids, but among them all we do not find the atrabiliary fluid. The cause of madness then cannot be attributed to this humour, and yet we dare not drive this disease from the seat it has so long held. In order to find reasons for keeping it there, they seek in the viscera for disorders which are not often found there even in the most striking cases, and which most often still exist without the least alteration in the intellectual functions.

in some individuals are the occasion of syncope. In such cases, it is easy to discover the seat of the affection, and such smaller effects of the passions on the heart, are very well calculated to throw light upon the nature of the greater.*

From these many considerations, we may conclude that the primitive seat of the attack in syncope, is the heart, which does not cease to act, because the action of the brain has been interrupted, but because it is the nature of some of the passions in such way to affect it, the brain at the same time, suffering a temporary death, because it no longer receives the fluid, which is necessary to its excitement. The nature of syncope is well enough illustrated, by the vulgar expression of being sick at heart.

It is of no importance to our present purpose, whether syncope depend on polypi, on aneurism, or be the result of some violent emotion. The successive affection of the organs is always the same. They die for the moment in the same way, as they really perish when the heart is wounded, or a ligature put upon the aorta. In the same manner also are those sorts of syncope produced, which succeed after any great evacuation of blood, pus or water.

* We should be often exposed to commit great mistakes, if we always judged by this rule. The sensation is a very uncertain means of determining the organ that is primarily affected; this can be proved by numerous examples, we shall cite one only which relates to the brain. Nausea and vomiting are often, as is well known, among the first symptoms of cerebral affections; should we from this believe that the seat of the disease is in the stomach? Undoubtedly not: now, in syncope produced by a strong affection of the mind, there is no reason to suppose that the heart is affected before the brain, since the intellectual phenomena have necessarily preceded the sensation of joy or of sorrow which has produced the syncope. But to say that the brain was primarily affected, is not saying that its action ceased before that of the heart; and every thing, on the contrary, leads to the belief that the loss of the senses is a consequence of the suspension of the circulation.

The heart is affected from sympathy, the brain for want of its excitant.*

Those cases of syncope which are occasioned by peculiar odours, by antipathies, &c. appear also to be attended with the same progression of symptoms, though their character be much less easily understood. There is a great difference between syncope, asphyxia, and apoplexy, in the first it is by the heart, in the second by the lungs, in the third by the brain that begins the general death of the body.

Death, as it happens in consequence of disease, in general exemplifies a concatenation of these different symptoms. The circulation, respiration, or cerebral action cease, the other functions are afterwards interrupted of necessity, but in these sorts of death, it rarely happens that the heart is the first to die. This however is sometimes the case. After long continued suffering, great suppuration, and sometimes, in dropsy, certain fevers, and gangrenes, one fit of syncope comes on after another,

* The syncope is produced in this case, from the sudden change in the circulation of the brain. But this change varies according to the seat of the effusion. If it be in the peritoneal cavity, the pressure that it makes interrupts the circulation in all the organs contained in the abdomen; the descending aorta is found compressed, and the blood, forced back towards the superior parts, accumulates in the sinuses and vessels of the brain. If the fluid be evacuated by puncture, the equilibrium is re-established in the different parts of the vascular system, the blood enters vessels which were before closed to it, it abandons in part those of the brain, and it is this sudden change in the circulation of the organ which produces syncope. If, on the contrary, the effusion be formed between the two layers of the arachnoides, and we can, as in spina bifida, evacuate the fluid by puncture, the vessels of the brain are immediately relieved of the pressure to which they had been subjected, and the blood, which before was forced back, towards the inferior parts, is driven forcibly into them; the change is, as must be perceived, the reverse of the preceding; but the result is the same, and syncope is produced in this case as in the other.

at last a longer one succeeds, and the patient dies, but whatever be the part affected, whatever the diseased viscus or organ, whenever the phenomena of death commence by the heart, they succeed each other as we have described them to do in sudden death, from lesion of that organ. In other cases, the heart is the last to act, is the ultimum moriens.

In general, in morbid affections, we much more commonly observe the ingress of death to be made by the lungs, than either by the heart, or the brain.

Whenever disease is terminated by syncope, the lungs are found to be almost empty, and if not affected by any organic disease, are collapsed, occupy a part only of the cavity of the thorax, and are of their natural colour.

The reason of this anatomical fact is simple. The circulation which has been suddenly interrupted, has not had time to fill the vessels of the lungs, as happens when death begins, by affecting the lungs or the brain. The truth of this fact I can vouch for, having frequently ascertained it by dissection, and in general, as often as death commences by the heart, or the larger vessels, such vacuity of the lungs may be considered as universal.

I have remarked it in the bodies of persons who have died from great hemorrhage from wounds or aneurismal rupture and violent passion, as well as in those who have suffered by the guillotine. The same phenomenon may be seen, by inspecting the lungs of any animal, which is killed in our butcheries.

In killing the animal slowly by the lungs, that organ might be filled with blood. Its taste would then be different from that which it naturally possesses, and resemble that of the spleen. Our cooks know well how to take advantage of that state of infiltration in which the latter viscus is generally found.

CHAPTER VI.

OF THE INFLUENCE OF THE DEATH OF THE LUNGS OVER THAT OF THE HEART.

We have already said, that the functions of the lungs are of two kinds, mechanical and chemical. Now the activity of this organ ceases sometimes by the former, and sometimes by the latter of these functions.

Any wound, which exposes the lungs on both sides, for a considerable extent, occasions their sudden collapse; any division of the spinal marrow, which suddenly paralyses the intercostals, and the diaphragm; any very strong compression exerted at the same time upon the whole of the thorax, and the parietes of the abdomen, any sudden injection of a large quantity of fluid into this cavity, are all of them causes which begin the death of the lungs, by putting an end to their mechanical functions. Those which influence in the first place their chemical functions, are the different sorts of asphyxia, strangulation, submersion, and a vacuum, in whatever manner produced.

I. *In what manner is the death of the heart occasioned by the interruption of the mechanical functions of the lungs.*

The interruption of the functions of the heart, can only succeed in two ways to that of the mechanical functions of the lungs: 1st. Directly, because a mechanical impediment is put to the circulation of the blood, by a state of collapse in the lungs. 2dly. Indirectly, because in such state the lungs no longer receive the materials, upon which their chemical functions are exerted, and therefore cannot transmit them to the heart.

Physiologists have all of them admitted the first mode of interruption, in the Pulmonary circulation. Reflected on themselves, the vessels of the lungs have not appeared to them, to be capable of transmitting the blood, on account of the numerous angles which they make. This idea they have borrowed from the phenomena of hydraulics, and it is their reason for the death which ensues, in consequence of a too long continued expiration.

Notwithstanding all which, it has been proved by Goodwyn, that in such case there remains a sufficient quantity of air in the air vessels, for dilating them enough to allow of the mechanical passage of the blood; he proves in consequence, that an unnatural permanence of the state, in which the lungs are placed from the act of expiration, does not affect the blood in the way, which is commonly believed. This is one step towards the truth, but we shall approach it much more nearly, and even attain it, should we be able to prove, not only that there remains a sufficiency of air in the lungs to permit the transmission of the blood, but that the very folds produced in the vessels by a state of collapse in the organ are not a real impediment to its course. The following observations and experiments will assuredly determine this fact.

1st.—I have already proved, that a state of fulness or emptiness in the stomach, and in all the hollow organs in general, produces no apparent change in the state of their circulation; and that the blood in consequence, will traverse the vessels, when bent or doubled upon themselves, as easily, as when they are distended in every direction. For what reason should a different effect be produced in the lungs, by the same disposition of the parts?

2dly.—There are different vessels in the œconomy which we may alternately bend or extend at pleasure: such are those of the mesentery, when exposed by an incision into the abdomen of the animal. Now in this experiment, which has been already made to prove the influence of the tortuous direction of the arteries upon the mechanism of their pulsation, if one of the mesenterics be opened, and then either bent or extended, in either case the blood will be thrown out with the same degree of violence, and in equal times will be emitted in equal quantities. I have always obtained the same result in this experiment which I have many times repeated. From analogy we might expect the same from the vessels of the lungs;* and from the following experiment it may be proved.

* It is not because the vessels of the lungs have become tortuous that the blood flows through them with difficulty, but because they are compressed. It was needless for Goodwyn to seek for reasons to prove, that the flattening of the lungs does not offer a mechanical obstacle to the course of the blood. If he had observed with attention the phenomena of respiration, he would have seen that this contraction, if it does not completely interrupt the circulation of the blood in the lungs, at least modifies it in a very remarkable manner. When the lungs contract, not only the bronchial cells are flattened, but the pulmonary vessels are compressed, and tend to expel the blood contained in their cavity. This fluid flows back then on one part towards the right ventricle by the pulmonary artery, and on the other it accumulates in the pulmonary veins before entering the left auricle. Hence we see that the jet by the carotid artery must increase rather than lessen in the last moments. But if the compression continues, as the capacity of the ramifications of the pulmonary artery is diminished as well as that of the veins of the same name, the quantity of blood which passes through the lungs is less, and the jet by the carotid necessarily decreases. The experiment related by Bichat is then entirely opposed to the opinion which he advances.

3dly.—Take a dog, cut the treachea, and adapt the tube of an injecting syringe to it, then make a vacuum in the

It is not only by influencing the course of the blood in the system of pulmonary vessels that the alternate motion of the thorax modifies the circulation. If we lay bare the jugular vein of a dog, we perceive that the blood does not move in its cavity from the sole influence of the right auricle, but in an evident manner from the influence of the motions of respiration also.

At each time that the thorax is dilated in inspiration, the vein is quickly emptied, flattened and its parietes are sometimes brought exactly against each other; it swells on the contrary and fills with blood when the thorax contracts. A similar phenomenon takes place in the venæ cavæ. In order to render it evident it is sufficient to introduce by the jugular vein into the venæ cavæ a sound of gum elastic; we then see that the blood flows through the extremity of the sound only during the time of expiration. A similar effect is observed if we introduce a sound into the crural vein and direct it towards the abdomen.

Haller and Lorry have paid much attention to this phenomenon, and have proposed an explanation of it which seems very satisfactory at first view, though it is really imperfect. When the thorax is dilated, say they, it draws the blood from the venæ cavæ, and, by degrees, that of the veins which are near it. The mechanism of this inspiration is very similar to that by which the air is drawn into the trachea. When the thorax contracts, on the contrary, the blood is crowded back in the venæ cavæ by the pressure which is made on all the pectoral organs, vessels, heart and lungs, by the expiratory powers, and by degrees arrives at the veins which terminate in them. Hence the alternation of vacuity and fulness which the jugular veins exhibit.

If we open an artery, and examine with attention the jet of blood, we see that it increases in expiration, and this is especially evident when the animal expires strongly or makes an effort; but as we cannot always produce these efforts at will, or a great inspiration, we can in some measure imitate the phenomenon and produce the contraction of the lungs by compressing with the hands the sides of the thorax; we see then the jet of arterial blood increase or diminish, in proportion to the pressure that is made. If respiration produces this effect on the course of the blood in the arteries, it is natural to think that it can influence the course of the venous blood, not only by means of the veins, as Haller and Lorry thought, but also by means of the arteries. For the purpose of satisfying myself, I made the following experiment. I tied lungs, and cut the carotid artery. It is evident, that according to the common belief, the circulation should be immediately suspended, in this experiment, since the pulmonary vessels from their ordinary state of distension,

the jugular vein of a dog; the vessel became empty below the ligature, and swelled much above, as uniformly happens. I punctured slightly with a lancet the distended portion, so as to make a very small opening. I obtained in this way a jet of blood, which the ordinary motions of respiration did not modify evidently, but which trebled or quadrupled in size if the animal made any considerable effort.

It might be objected, that the effect of respiration was not transmitted by the arteries to the open vein, but by the veins which were free, and which would have transmitted the blood of the venæ cavæ, towards the tied vein, by means of anastomoses. It is easy to remove this difficulty; in fact, in the dog the internal jugular vein is, as it were, but the appearance of a vein, and the circulation of the head and neck is performed almost entirely by the external jugular veins, which are very large. By tying at the same time these two veins I was sure of preventing, in a very great measure, the reflux which has just been spoken of; but so far from the double ligature diminishing the phenomenon before stated, the jet becomes on the contrary more strictly in relation with the motions of respiration, for it was evidently modified, even by common respiration; which, as we have seen, does not happen in the case of a single ligature. In order to render the thing more evident, I tried it on the crural vein; this vein and all its branches being furnished with valves, which oppose a reflux, if this phenomenon of the increase of the jet appears during expiration, we might be sure that the impulse came from the arteries. This is what I have observed in fact in many experiments. The crural vein being tied and punctured below the ligature, the jet which is formed increases evidently in powerful expirations, in the efforts and the mechanical compressions of the parietes of the thorax with the hands.

We see by this and the preceding experiments, that we cannot adopt without modification the expression of Haller and Lorry relative to the swelling of the veins. This swelling takes place, not only, as they say, by the flowing back of the blood of the venæ cavæ into the branches which open into them mediately or immediately, but also by the entrance into the vein of a greater quantity of blood coming from the arteries.

must have passed to the greatest possible degree of collapse, in consequence of the total abstraction of air; notwithstanding which the blood will be violently thrown out from the divided arteries for a certain time, and must consequently traverse the lungs: it will afterwards cease by degrees, but this, from causes which I shall explain hereafter.

4thly.—The same effect may be produced by opening, on both sides, the breast of a living animal, because the warm and rarified air of the lungs, will be more than balanced by the pressure of the colder air without;* now,

* As in dead bodies the air within and the air without are of the same temperature, the lungs, when they are full of it, do not flatten when the thoracic cavity is opened. There is usually then a space between the parietes and the contained organs; this is not because we die in expiration; for as the lungs empty themselves, the ribs and intercostal muscles rest upon them; it is because the pulmonary air, in cooling occupies less space, and the cells contracting gradually as the cooling takes place, diminish the whole size of the organ. A vacuum is then made between the pectoral and pulmonary portions of the pleura.

It is thus that, under some circumstances, the brain flattening and lessening after death, whilst the cavity of the cranium remains the same, a vacuum is formed between these two parts, which then exhibit an arrangement different from that of the living organs. If the sacs without an opening, as the peritoneum, tunica vaginalis, &c. never resemble, in this respect, the pleura and arachnoides; if their different surfaces are always contiguous after death, it is because the abdominal parietes or the skin of the scrotum, unable to resist the external air, flatten by pressure, and are brought against the internal organs, as the diminution of these tends to form a vacuum.

It is to this vacuum existing in the pleura of dead bodies, that must be referred the following phenomenon, which is always observed when the abdomen is opened and the diaphragm dissected. In fact, as long as no opening is made in this muscle, it remains distended and concave, notwithstanding the weight of pectoral viscera which rest upon it in a perpendicular situation, because the external air, which presses the concavity of it, forces it then into the vacuum in the thorax, which never exists during life. But the instant the air is admitted by a cut of neither in this case does the circulation experience any sudden change. For the sake of greater exactness, the

the scalpel, this muscular partition flattens, because the equilibrium is established. If all the air is drawn from the lungs by a syringe, the diaphragmatic arch is still more evident.

There is then this difference between the opening of a dead body and that of a living one, that in the first the lungs are already flattened, and in the second they flatten at the instant of opening. The contraction of the cells, from the condensation of the air by cooling, is an effect of the contractility of texture or from want of extension, which as we have said, continues in a degree with the organs after death.

Besides, if the lungs flattened in the dead body the instant the thorax was opened, it would be owing to the pressure of the external air, a pressure which would expel through the trachea what was contained in these organs. Now if, to prevent the escape of air, you close hermetically the canal by fixing a tube to it the stopper of which is tight, and the thorax is afterwards opened, the lungs still flatten ; the air had already gone out of them. Make, on the contrary, the same experiment on a living animal, you will always prevent the flattening of these organs, by preventiug the expulsion of the air.

In this point of view Goodwyn has gone on a wrong principle in measuring in a dead body, the quantity of air remaining in the lungs after each expiration. Besides, if you open bodies ever so little, you will hardly find two in which there is the same arrangement in the lungs. The infinitely various manner in which life terminates, by accumulating more or less blood in these organs, by retaining more or less air in them, &c. gives them so variable a size, that no general data can be established respecting them. On the other hand, can we hope to be more successful on the living body ? No ; for who does not know that digestion, exercise, rest, the passions, tranquillity of mind, sleep, watchfulness, temperament, sex, &c. make an infinite variety in the forces of the lungs, the rapidity with which the blood circulates through them, and the quantity of air that penetrates them ? All the calculations on the quantity of this fluid which enters or goes out according to the inspiration or the expiration, appear to me to be physiological errours, inasmuch as they assimilate the nature of vital forces with that of physical forces. They are as useless to science as those which had formerly for their object the muscular force, the velocity of the blood, &c. Besides, observe if their authors agree better among themselves then they used to do on this much agitated point.

little air remaining in the cells of the organ may be voided by a syringe.

Along with these observations let us place the facility with which the pulmonary circulation continues to be made, when collections of water, pus, or blood, are lying within the pleura, or pericardium. In these cases the air vessels are often prodigiously contracted, and consequently the vessels of their parietes doubled and bent.* If this state be taken into consideration, we shall have sufficient data for concluding that the tortuous disposition of the vessels, can never be an obstacle to the passage of the blood; and therefore, that the interruption of the mechanical functions of the lungs, can never directly put a stop to the action of the heart, though it may do so indirectly, in impeding the exercise of the chemical functions of the lungs.

If then we can determine why the heart remains inactive, when the latter phenomena are annihilated, we shall have resolved a double question.

Many authors have asserted that the death, which ensues after a too long continued inspiration, is owing to the mechanical distension of the pulmonary vessels by the rarified air, a distension impeding the circulation.

* It is inconceivable how Bichat could think of confirming his opinion by the example of hydrothorax. Who does not know that when an effusion takes place in the cavity of one of the pleuras, that that portion of the lungs only which is above the level of the water serves the purposes of respiration; that when the effusion has arrived to the summit of the cavity, the lungs of that side, which can no longer dilate, are of no use in respiration; and those of the other, being compelled alone to make the necessary modifications in the blood, must be traversed by the greatest part of this fluid? It is known, finally, that in this case the patient cannot lie down an instant on the sound side, because this position prevents the dilatation of the lungs of that side which alone serve for respiration, and the danger of suffocation is therefore imminent.

But this reason also is as false a one, as that which we have already disproved. Inflate the lungs as powerfully as may be, then tie the trachea and open the carotids, and the blood will flow as impetuously, as when the respiration was perfectly free.*

II. *Why does the heart cease to act, when the chemical functions of the lungs are interrupted.*

According to Goodwyn, the reason why the contractions of the heart are stopped, when the chemical functions of the lungs have ceased to be performed, consists in the want of that excitement which the red blood only can produce upon the red-blooded ventricle. This ventricle, says he, has not a sufficient stimulus in the black blood, and death is occasioned because it no longer is capable of transmitting any thing to the different organs. In this case death must happen, as it would from ligature of the aorta—precisely in the same way as when its source is exclusively in the heart. The other parts die only for want of blood, just as when in a machine, the principal spring being taken away, the others cease to act, because they are not put into action.

On the contrary, I am persuaded that there is a general affection of all the parts, whenever the chemical functions of the lungs are suspended; I am persuaded that the black blood continues to be pushed on for some time by the aorta, and that its influx into the organs is the occasion of their death; that the organs die in fact, not because they do not receive blood, but because they do not receive red blood; in a word, that they are penetrated

* The observation of Bichat is very just; and I have myself often observed in cases of apoplexy, that the motions of the heart continue many hours after the arteries contain only black blood.

by the material cause of their death; so much so, that we may asphyxiate any isolated part at will, by injecting it with venous blood while all the others shall continue to receive the red blood of the heart. At present I shall inquire into the phenomena of the contact of the black blood with the parietes of the ventricle, and refer the reader to the following chapters, for its effects upon the other parts.

The movements of the heart may be stopped and made to cease altogether from the influence of the venous blood in two ways.—1st. As Goodwyn has said, because the left ventricle is not excited by it upon its internal surface.—2dly. Because such fluid, when carried into the substance of the heart by the coronary vessels, must act upon the muscular fibre of the heart in the same way as it does upon the other muscles. Now, for my part, I am assured that the black as well as the red blood, will excite into contraction the internal surface of the aortic ventricle. The following observations and experiments will confirm my assertion.

1st. If asphyxia were to be followed by the consequences which Goodwyn has supposed, it should influence the heart in the first place; the annihilation of the functions of the brain, as in syncope, should be only secondary; nevertheless, asphyxiate an animal, by stopping up the trachea, by placing him in a vacuum, by opening the chest, or plunging him into carbonic acid gas, and it will in every instance be observed, that his animal life is the first to be interrupted, and that the creature externally is dead; but that within the heart continues for some time afterwards to act, and the pulse to be felt.

In this way the symptoms of asphyxia are not the symptoms of syncope. In the latter the cardiac and cerebral actions are suspended at the same instant, in the former the heart survives, as in cases of strong concussion of the brain for many seconds. It follows, that in asphyxia, the different organs do not cease to act, because the heart has ceased to supply them with blood, but because it no longer supplies them with that sort of blood by which they can be stimulated.

2dly. If the trachea of an animal be stopped, and an artery opened, the colour of the blood which it emits, will gradually be changed, and at last become as black as that of venous blood. Now, notwithstanding this phenomenon, which is as apparent as it can be, the fluid for some time afterwards is thrown out full as strongly as it would be, were it red. I have seen a quantity of black blood discharged in this way, more than sufficient to kill the creature from hæmorrhage; were it not already dead, in consequence of its asphyxiated state.

3dly. In the last-mentioned experiment, it may, indeed, be alleged, that some remains of air in the air cells, might, as long as the black blood continued to flow, have communicated to it a principle of excitement; but to put it out of all doubt, that the venous blood does really pass into the aortic ventricle, unaltered in its passage from the corresponding cavity, the air may be entirely pumped out of the lungs with a syringe, by exposing the trachea, in the first place, and then adapting the instrument to the transverse section of the tube; after this, let the carotid be opened; now as soon as the red blood contained in this artery is exhausted, the black blood will succeed to it, and that, without undergoing a variety of gradations in colour; in this case also for a time, the jet will be very powerful, and only be gradually weakened; but if the black blood were not an excitant to the heart, its interruption should be immediate.

4thly. The following is another proof of the same nature. Expose the breast on one side by sawing exactly through the ribs before and behind: when this is done, the lungs on that side will collapse. Proceed to open one of the pulmonary veins; fill a syringe warmed to the temperature of the human body with venous blood, then push it into the red-blooded ventricle. Now, according to the common opinion upon the subject of asphyxia, such fluid should at least diminish in a sensible way, the movement of that cavity, notwithstanding which, in four successive experiments, I could not observe any such diminution. On the contrary, in one of them, on pushing the piston, the strokes of the heart were augmented in number.

5thly. If the black blood be not an excitant to the heart, it can only want such power, because it contains more carbon and hydrogen, than the red blood;* but if the heart of an animal which has been killed expressly for the experiment, by lesion of the brain or of the lungs, has ceased to beat, it may, notwithstanding, be made to contract as long as it preserves its irritability, by throwing into the aortic ventricle either hydrogen gas, or carbonic acid gas. It follows, that neither hydrogen gas nor carbon can act as sedatives to the heart.

The experiments which I made and published last year, on the emphysemata, produced in different animals with these gases, have established the same truth with respect to the muscles, since they do not cease to move in consequence of such experiments, and after death, preserve their irritability as they usually do.

* At the period Bichat wrote, it was impossible to know whether the arterial or venous blood contained most hydrogen and carbon. At the present day even, when the means of analysis are much more perfect and animal chemistry farther advanced, we are hardly better informed.

Lastly. I have often succeeded in re-establishing the contractions of the heart, which have been annihilated in different sorts of violent death, by the injection of black blood into the red-blooded cavities, with a syringe adapted to one of the pulmonary veins.

Thus it is proved, that the red-blooded heart does actually push the black blood into all parts of the body; and in this way is the colour given to the different surfaces, of which, in one of the following chapters, I shall offer a sketch.

Neither does the simple presence of the black blood act in a more sedative way upon the internal surfaces of the arteries.* If, in fact, while the tube adapted to the trachea is shut, the blood be made to flow from an artery of the foot, it will be thrown out for some time, with the same force which it would have been, were the pipe to be open. The action, then, which it exercises in its passage from the heart, upon the parietes of the arteries, does not diminish the energy of these parietes. When this energy decreases, it is at least in part from a different cause.

From the above experiments we may conclude, that the black blood arriving in mass at the red-blooded ventricle, and correspondent arterial system is able, from its sole contact with them, to occasion the action of these cavities; we may be equally certain, that were not the functions of these parts suppressed from other causes, the circulation would continue to be made in a very sensible manner, at least, if not with force.

Of what nature, then, are the causes which interrupt the circulation in the heart and arteries when they are

*It seems that when Bichat wrote this work, he had not fixed in his own mind what part the arteries take in the circulation; at least, in this paragraph, he seems to give them a contractile power, which, in his other works, he accords only, to their ultimate ramifications.

supplied with venous blood? for when this has been flowing for some time, the jet of it is gradually weakened, and ceases at last entirely; yet if the cock of the pipe be opened, it will be restored with vigour.

I am persuaded that the black blood acts upon the heart as it does on all the other parts, as we shall see that it affects the brain—that it affects the voluntary muscles, the membranes, and the system in general; the tissue of which it penetrates and operates within it as a debilitant upon each individual fibre. I am fully of opinion, that the circulation would be almost as quickly interrupted as in the preceding cases, were it even possible to supply the coronary arteries of the heart with red blood, while the black blood is transmitted to the various parts of the body by the aortic auricle and ventricle.

The black blood operates by its contact with the fleshy fibres, at the extremity of the arterial system and not by its contact with the internal surface of the heart. Thus it is only by little and little, and when each fibre has been as it were injected, that the powers of such fibres diminish and cease. On the contrary supposition, their cessation and diminution should be almost sudden.

It may be demanded in what manner the black blood acts at the extremities of the arteries, upon the fibres of the different organs. Is it upon the fibres themselves, or upon the nerves which are distributed to them? I am rather inclined to suppose the latter to be the fact, and to consider asphyxia as an effect produced in general by the black blood upon the nerves, which every where accompany the arteries of a certain diameter: for as we shall presently see, the debility which in such case the heart experiences, is only a particular symptom of a disease in which the organs in general are the seat of a like debility.

It might be demanded also in what way, that is to say, by what manner of influence, the black blood acts upon the nerves or fibres. Is it from the principles which it actually contains, or from the absence of those which are proper to the red blood? Is oxygen the principle of irritability—are hydrogen and carbon the reverse?

These questions have been sufficiently disputed.—Let us stop when we arrive at the limits of rigorous observation. Now, I think, that we shall establish an assertion the most strictly conformable with such principle, in saying generally and without determining the manner, that the heart ceases to act, when the chemical functions of the lungs are interrupted, because the black blood with which its fleshy fibres are penetrated, is not of a nature to keep up their action.

From this manner of regarding the phenomena of asphyxia with relation to the heart, it is evident that both the ventricles should be equally affected by it, because their parietes must be equally injected with venous blood. Nevertheless, it is constantly observable, that the movement of the red-blooded heart is the first to stop; that the black-blooded heart in every case the ultimum moriens; but this phenomenon does not suppose a more real, a more decided debility in the one, than in the other heart; for as Haller observes, the fact is common to every kind of death in the red-blooded animal, and not the case particularly in asphyxia.—Besides, were the red-blooded heart the first to be absolutely affected, as the theory of Goodwyn supposes, the following would be the appearances on opening the asphyxiated subject.—1st. A distension of the corresponding auricle and ventricle, by the black blood which they would not be able to expel into the aorta.—2dly. An equal fulness of the pulmonary veins and lungs.—3dly. A consequent fulness and swelling of the pulmonary artery and the black-blooded cavities. In a word, the congestion of the blood should be the greatest in that of its reservoirs, whose action is the first to cease.

But this is contrary to observation—for 1st. In the asphyxiated subject, the red-blooded cavities and pulmonary veins, contain but a very small quantity of blood in proportion to that which distends the opposite heart. 2dly. The place where the blood has stopped, is found to be principally in the lungs, in the lungs must we begin to follow its accumulation into the venous system. 3dly. The arteries are as full of blood as their correspondent ventricles, and consequently it cannot be in the ventricle more than elsewhere, that death has been begun.

But what is the reason why the black-blooded heart is the last to beat? because, says Haller, it is the longest excited; because it contains a greater quantity of blood; because the blood is sent into it from the largest veins of the system, and regurgitates from the lungs. The famous experiment is well known by which in emptying the black-blooded cavities, and tying the aorta so as to retain the blood within the red-blooded cavities, the contractions of the latter are prolonged so much beyond the contractions of the former. But in this experiment it is manifestly the black blood which accumulates in the aortic auricle and ventricle, because the breast must be preliminarily opened, and therefore the lungs collapse.

Should a more direct proof be required, immediately before the experiment, let the trachea be closed with a syringe, and the air of the lungs be voided; the experiment will just as well succeed; besides, the operator to be sure of the colour of the blood in the aortic cavities, has nothing more to do than to open them, as soon as he has finished his experiment.

We shall conclude that the black blood is almost as powerful a stimulus as the red blood to the inner surface of those cavities, which usually contain the latter only: the reason why they are the first to be arrested in their action, is, because they do not receive so large a quantity of blood as the others.

Notwithstanding what I have said, I do not entirely reject the idea of the red-blooded ventricle being not excitable by the black blood. It may indeed be less excitable by this sort of blood, than by the other; but I believe that the preceding considerations will reduce this difference of excitement to a mere trifle.

The following, however, is an experiment where such difference would appear to be very manifest. If a stop cock be adapted to the trachea, and an artery opened, the blood will blacken, and continue for some time to be thrown out with its ordinary force, but at last the jet will gradually grow weaker. If, after this, the air be admitted, the blood will almost immediately become red and its jet be visibly augmented. In this case the sudden augmentation appears at first to depend upon the simple contact of the red fluid with the sides of the aortic ventricle, since it has not had the time to penetrate the tissue of the heart; but let things be a little attentively examined, and it will soon be seen that this impetuosity of impulse, depends on the movements of inspiration and expiration, to which the animal is obliged, on the admission of air into the lungs. The heart excited at its exterior, and perhaps a little compressed by these movements, is the occasion of such phenomenon, and expels the blood with a force which is far beyond that which results from its habitual contractions.

What I have here advanced is proved, by the manifest diminution of the jet, as soon as once the lungs have taken on their accustomed degree of action. Besides, the influence of a series of full expirations may be manifested without dividing the trachea. Open the carotid and precipitate the respiration of the animal by tormenting it (for pain will constantly have this effect) and the jet of blood will be visibly increased. The same augmentation may be artificially produced, by suddenly compressing the parietes of the thorax. These experiments succeed best on animals already weakened by the loss of a certain quantity of blood.

In the ordinary state of health however, a series of strong expirations will not be found to quicken the pulse. Of this I cannot assign the reason.

From what we have now said, it follows, that the experiment, in which, on the opening of the cock of the syringe, the blood is thrown out with augmented force, is not so conclusive as might at first be imagined. I confess that it embarrassed me much for many days, I hold then my former conclusions to be good.

In the red and cold-blooded animals, the action of the lungs has not so immediate a connexion with that of the heart, as it has in the red and warm-blooded animals.

I tied the lungs of two frogs at their basis, having previously exposed them, by incisions made laterally into the breast, the circulation however continued as usual for a considerable time. After this experiment, I have seen on opening the breast, the movements of the heart precipitated, a circumstance depending no doubt upon its contact with the air.

I shall finish this chapter by the examination of an important question, and inquire into the reason, why when the chemical functions of the lungs are stopped, the pulmonary arteries, the black-blooded cavities of the heart, and in a word all the venous system, are found so much more full of blood, than the aortic system. In such case the circulation appears at first to be interrupted in the lungs, and then in the other parts, according to their proximity to the lungs.

This phenomenon must have been observed by all who have opened the asphyxiated subject. It has been explained by Haller and others, from the tortuosity of the vessels; but this opinion I have sufficiently refuted.*

But before I proceed to assign a more real cause, I shall observe, that the lungs, (when the blood is first arrested, because it finds in them the first obstacle to its progress,) are found in a singularly various state, according to the kind of death of which the individual has died. In sudden, in instantaneous death, neither the lungs, nor the black-blooded heart are very much distended.

I have observed this fact, 1st. In the bodies of two persons who had hanged themselves and were brought into my amphitheatre. 2dly. On two subjects who had fallen into the fire, and were instantly suffocated. 3dly. On dogs which I have suddenly drowned. 4thly. Upon guinea-pigs, which I have killed in a vacuum, or in different gases, or otherwise.

On the contrary, arrest the phenomena of respiration in a gradual manner; drown the animal by plunging him in water, and taking him out alternately, asphyxiate him

* It is certain, whatever Bichat may say concerning it, that numerous angles in the course of a blood-vessel, by increasing the friction, must retard the course of the fluid which runs through its cavity. We may in fact believe that it is one of the causes, which, in the flattening of the lungs, embarrass the circulation; this cause exerts its action principally upon the last ramifications of the pulmonary artery which, by their interlacing, form the bronchial cells; another more powerful cause, which acts equally on the divisions of the vein and the artery is, as we have said, the pressure made on the lungs by the flattening of the thorax, and the elevation of the diaphragm.

by placing him in a vessel of gas imperfectly closed, continue as long as possible such state of pain and anguish, and the lungs will be found extremely full of blood.

Between the extreme fulness, and the almost complete emptiness of the pulmonary vessels, there is a variety of degrees; now by the manner in which we kill the animal, we can determine any one of these degrees at will: It is in this way that we must explain that state of fulness in the lungs of such subjects, as are usually brought into our amphitheatres: in the greater number of cases, the attacks of death are slow and gradual.

But whatever be the state of the lungs in the asphyxiated subject, the venous system is full of black blood, especially about the heart. In this respect, there is always a very wide difference between the veins and the arteries, and accordingly the blood must find in the lungs the principal obstacle to its circulation: such obstacle, as we have said, does not proceed from the tortuosity, and state of collapse in the pulmonary vessels; its causes are relative, first to the blood, secondly, to the lungs, thirdly to the heart.

The principal cause depending on the blood, consists in the great quantity of this fluid, which passes from the arteries into the veins. In fact we shall soon see, that the black blood when it circulates in the arteries, is not capable of furnishing the materials of secretion, exhalation, or nutrition, or if it be so, that it is not a stimulus to the organs which are the agents of these functions.*

* See the article on the influence of the lungs on all the parts. I am compelled here to deduce consequences from principles which I shall prove hereafter; such is in fact the connexion of questions which have the circulation for their object, that the solution of one draws as a necessary consequence that of all the others. It is a circle in which it is always necessary to suppose something, leaving it to be proved afterwards.

It follows as a necessary consequence, that the portion of fluid which is usually taken up from the arterial system by these different functions, flows on into the venous system, together with the portion which should naturally pass thither; hence there must be contained a greater quantity than usual in the veins; and therefore a greater difficulty be experienced in its passage through the lungs. Practitioners in opening the bodies of asphyxiated persons, have always remarked the abundance of blood which is met with there. The fact has been particularly remarked by Portal, and I have always found it in my experiments.

The causes of obstacle to the passage of the blood proceeding from the lungs, are first the non-excitement of this organ by arterial blood. In asphyxia, the bronchial arteries are penetrated by the black blood as well as the rest. Hence its obscure and dusky colour in this case. This colour and its successive shades, may be easily remarked in the collapsed lung, when the chest is opened; but in asphyxia, such blackness is principally owing to the colour of the blood, contained in the pulmonary veins.

The black blood when circulating in the bronchial vessels, produces upon the lungs the same effect which it does in the heart, by penetrating the coronary arteries; it weakens the different parts—impedes their action, and the capillary secretions which should be made there, from the tonic powers of the organ.

The second cause of obstacle to the circulation, when the chemical functions of the lungs are interrupted, is the non-excitement of the organ by vital air. The first effect of such air upon the mucous surfaces of the air-cells, is to stimulate them, and so to keep them up in a sort of perpetual erethism.* In the same way are the powers of the stomach brought into action by the presence of aliment there, and those of every reservoir of the body, by the influx of their accustomed fluids. Again, such excitement of the mucous surfaces by foreign substances keeps up their tone. The privation of such excitement, therefore, must put a stop to their capillary secretions, which depend upon their tonic powers.

The different aeriform fluids which take the place of the atmospheric air in the different sorts of asphyxia, appear to act very differently upon the tonic powers, or the insensible organic contractility of the lungs. Some of these put a sudden stop to the circulation, others not. Compare the asphyxiæ produced by nitrous or sulphurated hydrogen gas, with those which may be occasioned by pure hydrogen, or carbonic acid gas, and the difference will instantly be seen. This difference indeed, as well as the various other phenomena observable in the various asphyxiæ, depends on causes which we have not mentioned, but the affection of the air-cells, is evidently one of them.

Lastly, the third cause of stagnation of the blood in the venous vascular system, is that debility, which takes place in the ventricle and auricle of this system, when penetrated with venous blood: on the influx of the blood from the cava, they are consequently distended, and this is the case also with the cava itself, for the very same reason. The causes which are now assigned, are sufficient to shew why the black-blooded system, is gorged with

* I cannot see what can have induced Bichat to admit this erethism of the lungs, the use of which cannot be imagined. It is quite enough to suppose in the organs the existence of those concealed properties, when there is need of them to explain their functions.

fluids in asphyxiæ.* The following considerations will shew why the red-blooded system contains a lesser quantity of fluid.

1st.—The obstacle commences in the lungs; therefore the aortic heart must receive a less quantity than usual: hence, as we have seen, proceeds the quicker cessation of the contractions of this ventricle.

2dly.—The natural strength of the arteries, though enfeebled by the influx of blood into their parietes, is much superior to that of the veins, which besides are subject to the same cause of debility.† Accordingly these vessels and the aortic ventricle, are capable of surmounting the resistance of the capillary vessels of the body in general, much more easily than the veins and the venous ventricle, are of vanquishing the capillaries of the lungs.

* As the blood flows in the veins in a continuous motion, the distension of these vessels does not take place in the direct motion of the blood, but in its retrograde motion. Every time the right auricle contracts, a portion of blood, instead of passing into the ventricle of the same side, is forced back into the superior and inferior venæ cavæ, and into the principal venous trunks which open into them. By this reflux of the blood, these veins are dilated, and have a pulsation which is easily seen in the jugular in very thin people. This pulsation has received the name of the *venous pulse.* When it is very evident, it may indicate an obstacle to the passage of the blood from the auricle to the right ventricle.

Another reflux of the blood in the veins corresponds with the moment of expiration, and is perceptible even longer. We shall soon have to speak of it, in speaking of the *movements* of the brain.

† *The natural force of the arteries* is not dependent on life, and consequently cannot be enfeebled by the entrance of black blood. This force is nothing but elasticity, which indeed ceases to be in action as soon as death takes place, but which does not cease to exist till the texture itself is destroyed and disorganized. As this property is very conspicuous in the arteries, it is sufficient to drive the blood from their cavity at the instant of death, whilst it is too feeble in the veins to expel this fluid entirely. Thus it is, that we find blood in the veins only, after death.

3dly.—In the general capillary system, there is only one cause of want of action, viz. the presence of black blood in it; to this in the lungs there is added another cause, the want of that habitual excitement which this organ receives on the part of the atmospheric air: accordingly in the lungs, there is a greater resistance offered to the influx of the blood, and with respect to the heart, a less capability of surmounting such resistance. In the other parts, the contrary of all this is observed, a less resistance to the influx of the blood from the arteries into the veins on the one hand, and on the other a greater capability of overcoming such resistance.

4thly.—In the general capillary system, which is continued on from that of the arteries, if the circulation be embarrassed at first, in any organ in particular, it may still continue to go on in the other organs, more or less, in which case the blood regurgitates by these others into the veins. On the contrary, as all the capillary system, which is the continuation of the general venous system, is concentrated in the lungs, the venous circulation must be suppressed, whenever this organ loses its powers.

The preceding considerations, if I am not mistaken, explain why the vascular systems are so unequally full of blood after death, a circumstance, which is common to almost every disease, as well as the asphyxiæ.

In the latter sort of death however, although the general capillary system presents a less degree of resistance than is made by the capillary system of the lungs, nevertheless such resistance arising from the influx of the black blood into the organs in general is very manifest, and produces two remarkable phenomena.

The first is a greater quantity than usual of black blood in the arteries, and therefore a greater difficulty of injecting these vessels. Such blood is seldom coagulated.

Indeed in all cases the venous blood is much less coagulable than arterial blood. This fact is proved, 1st, By the experiments of modern Chemists. 2dly, By the comparison of the blood of varices with that of aneurisms. 3dly, By the inspection of that which usually stagnates after death in the veins of the neighbourhood of the heart.

The second circumstance, to which I have referred, is the general livid colour of the greater number of the surfaces, with the fulness of divers parts, such as the face, the tongue and lips. These two phenomena indicate a stagnation of the blood at the extremities of the arteries, in the same way as they denote the same effect in the pulmonary vessels; here there is a much more evident repletion, because as I have said, the capillary system is there concentrated within narrow limits.

The reflux of the blood of the veins towards the extremities is the reason assigned by authors for the livid appearance of asphyxiated persons. There is little reality in this cause: in fact, this reflux, which is very sensible in the trunks of the veins, diminishes continually towards their ramifications, where it is impeded and rendered impossible by the valves, besides which, the following experiment is an evident proof, that we must attribute the lividity in question, to the impulse of the black blood from the aortic ventricle.

1st.—Adapt a syringe with its stop-cock to the divided trachea. 2dly, Open the abdomen so as to distinguish the intestines and epiploon. 3dly, Shut the cock. At the end of two or three minutes, the red tint which animates the peritoneum, and which is borrowed by this membrane from the vessels, which creep underneath it, will be changed into a dull brown colour. This colour may be made to disappear and re-appear at will, by opening or shutting the syringe.

Here we cannot, as if the experiment were made upon other parts, suspect that a reflux is propogated from the right ventricle towards the venous extremities, since the mesenteric veins, together with the other branches of the vena portæ, form a system apart, independent of the great black-blooded system, and having no communication with the cavities of the heart which correspond with this system.

But I shall touch again upon this subject. The above experiment is amply sufficient to prove, that the lividity of the surfaces of the body is owing to arterial impulse.

At present we are in a condition to explain how the lungs are more or less gorged with blood, more or less livid, and how the livid spots upon the different parts of the body are more or less marked accordingly as the asphyxia has been more or less prolonged : for it is evident, that if before death, the black blood have gone round the two systems ten or twelve times, it will inject the extremities much more than if it had made such circulation only two or three times ; at each revolution, a greater or less quantity will be left in the extremities, for want of action in the capillary vessels.

In finishing this chapter I shall take occasion to observe, that the spleen is the only organ of the economy susceptible like the lungs of assuming a very great variety of volume. Scarcely is it ever found in the same state. It has been falsely supposed that there is a relation between the plenitude or vacuity of the stomach, and the inequalities of the spleen ; but this is not the case, as I have said elsewhere. Such inequalities during the life of the body do not exist, and supervene only at the instant of death.

It appears to me, that they depend especially upon the state of the liver, the capillary vessels of which, are the continuations of all the branches of the vena portæ as the capillaries of the lungs are those of the great venous system. Thus, when the hepatic capillaries from any cause whatever are enfeebled, the spleen must swell and be filled with the blood, which cannot traverse the liver.* In such case, if I may so express myself, there is an isolated asphyxia of the abdominal vascular apparatus. The liver being to the spleen, what the lungs are to the black-blooded cavities in common asphyxia. The resistance is in the former, the stagnation in the latter. But this matter may be better understood hereafter. Exriments upon animals killed in different ways, would throw much light upon it, and these I purpose undertaking. By these means we may rigorously establish the

* The state of the spleen in the dead body may become in some measure an index of the state of the circulation during the last moments of life. The swelling of it shows almost always the embarrassment of the circulation; and not only in an insulated system, such as that of the vena porta, as Bichat considers it, but in the whole pulmonary system.

When any cause impedes the circulation in the capillaries of the lungs, it necessarily produces a stagnation of the blood in the divisions of the pulmonary artery, and by degrees the disturbance is felt even in the two venæ cavæ, but especially in the inferior, in which the blood rises against its gravity. The blood accumulates in the principal branches; the veins of the liver and kidneys swell more or less; as to these organs themselves, the firmness of their texture hardly allows them to be distended, so they do not increase sensibly in size, or if this increase takes place, it is slow. It is not the same with the spleen; the looseness of its texture will admit a great quantity of liquid, and its size can thus be doubled or trebled in a very short time. It becomes then a kind of reservoir, in which is accumulated the blood which cannot pass through the lungs.

It may be objected to what we have just said, that oftentimes in phthisis the greatest portion of the lungs has become incapable of allowing the blood to pass, and that yet after death, the spleen is found in a natural state. But it should be recollected, that phthisical patients have, during the latter part of their lives, but very little blood, so that each portion sent by the right ventricle always finds a sufficient channel for it in the lungs.

analogy existing between the stagnation of the blood in the different branches of the vena portæ, and that which is observed in the general venous system, in consequence of various kinds of death. With respect to the spleen and its system of veins, in ordinary asphyxia, I have never remarked in it any peculiarity.

CHAPTER VII.

OF THE INFLUENCE OF THE DEATH OF THE LUNGS OVER THAT OF THE BRAIN.

We have just seen, that in asphyxia, the movements of the heart are paralyzed, because its fleshy fibres are penetrated with venous blood. This fact should indicate the same to be the case with reference to the action of the brain. It is indubitably proved by experiment.

Whatever be the manner in which the pulmonary functions are interrupted, it is always the interruption of the chemical changes, which troubles the functions of the brain.* What I have said upon this point with respect

* In a preceding article, Bichat maintains that the entrance of the arterial blood contributes to support the action of the brain, principally by the jar which it communicates to this organ. It is astonishing, after this, that he should attribute the suspension of the cerebral functions to the interruption of the chemical phenomena of respiration rather than to that of the mechanical phenomena. He could not however be ignorant, that it is to the last that must be referred the greatest of the two motions with which the brain is constantly agitated.

These motions of the brain in relation with those of respiration have been for a long time observed. Schitling has described them in a memoir inserted in the first volume of the Memoirs of Learned Foreigners. He has shown that the brain rises in expiration, and flattens in inspirato the heart, is exactly applicable to the cerebral mass : I shall not repeat it. It remains to shew by experiment,

tion. Haller, Lamure and Lorry have since him investigated this motion, and they have given an explanation of it, which is defective only because they have been ignorant of the influence of respiration on the acceleration of the course of the blood in the arteries through the medium of the capillary vessels.

At the time of a strong expiration, all the pectoral and abdominal organs are compressed, and the arterial blood is forced more especially into the branches of the ascending aorta. This blood goes then in greater abundance towards the head, and has a tendency to pass more quickly in the veins which carry it towards the heart; which would take place immediately if the veins were free. But the pressure made on the pectoral organs has also made the venous blood flow back in the vessels which contain it. Now, this blood has just met that which comes from the arteries; the vessel is distended, and the course of the fluid is arrested in the veins; from that the brain swells and rises up; but as soon as expiration has ceased, the dilatation which takes place in the chest attracts, in some measure, the blood of the superior venæ cavæ; the veins which enter it are soon emptied and the brain flattens down.

In reflecting on the mechanism by which this movement of the brain is effected by the influence of respiration, we cannot perceive why the phenomenon should be limited to the organ contained within the cranium, and especially why the spinal marrow should not equally partake of it. The continuity of this organ with the cerebrum and cerebellum, its situation in a cavity which it does not entirely fill, the numerous arteries which it receives from the intercostal and vertebral arteries, the number and size of its veins destitute of valves are so many circumstances which should favour the accumulation of the blood at the time of expiration, and consequently produce its swelling. For the purpose of seeing if my conjectures were well founded, I have made some experiments; I laid bare in a young rabbit the spinal marrow at about the eighth or ninth dorsal verterbra, I saw it perfectly whole and surrounded by its coverings. At first I perceived no motion, but soon the animal being much incommoded by the position in which I kept him, made a deep inspiration, and then I saw distinctly the spinal marrow flatten, and a small vacuum between the dura mater and the osseous parietes of the vertebral canal. In the following expiration, and the observation of diseases, that when the chemical functions of the lungs are put a stop to, it is the black blood which interrupts the action of the brain and that of the nervous system. In the first place let us examine our experiments.

I first began by transfusing into the brain of an animal, the arterial blood of another, that this essay might serve as a point of comparison for others. Open one of the carotids of a dog; tie the extremity towards the brain, and fasten a tube to that which is next the heart; then open the carotid of another dog, tie the extremity of the vessel next the heart, and fix the other end of the tube into that which is next the brain; then let the assistant, who meanwhile should have had his fingers upon the artery of the first dog underneath the tube, remove his compression, and the carotid of the second dog will be seen beating under the impulse of the blood injected from the heart of the first. This operation fatigues but little the animal which receives the blood, particularly if one

the spinal marrow resumed its original size. I was unable to see any thing more in this animal.

I laid bare in a dog of middle size, the spinal marrow, a little above the lumbar region; I could not mistake there a very evident motion, in relation with respiration: a flattening during inspiration, and a swelling during expiration. The phenomenon was so marked, that the air entered the vertebral canal with a noise, whilst the animal inspired, and was forced out when the animal expelled the air from his lungs.

For the purpose of satisfying myself that this motion took place in the spinal marrow and not in the dura-mater, I cut this membrane in the whole extent of the opening made in the vertebral canal, and I was able easily to convince myself that the motion was from the swelling of the spinal marrow. I am not however certain that there is not a slight rising of the organ from the dilatation of the large veins in the anterior part of the vertebral canal, but this dilatation cannot be considerable, on account of the fibrous layer which covers the posterior face of these veins.

of the veins be previously opened, to prevent too great a fulness of the vessels. It will live very well afterwards. This experiment has been often repeated, and always with the same results.

After this experiment, I opened the carotid, and the jugular vein of another dog, and after tying the extremity of the carotid next the heart, received the blood of the jugular into a warm syringe, and injected it into the brain. The creature appeared immediately to be agitated, breathed quickly, and seemed to be in a state of suffocation, similar to that of asphyxia. Its animal life became entirely extinct; the heart, however, continued to beat, and the circulation to go on for half an hour afterwards; at the end of which time the organic life was terminated also.

This dog was of a middle size, and about six ounces of blood were injected with a gentle impulse, for fear of that being attributed to the shock, which ought to have been the result of the nature and composition of the fluid. I repeated this experiment upon three dogs the same day, and afterwards at different times upon others; the result was invariable, not only as to the asphyxia of the animal, but even as to the concominant appearances.

It might be thought that out of its vessels, and exposed to the contact of the air, the blood might imbibe a pernicious principle, or be deprived of that which is requisite for the maintenance of life. It might be imagined, that to this cause was owing the sudden death of the dog, on the injection of the brain with venous blood. To shew that this was not the case, I made a small opening in the jugular of a dog, to which I adapted a moderately warm syringe, and pumped the blood immediately from the vein.—It was afterwards thrown into the carotid: the symptoms were the same as the preceding, but less marked, and the death of the creature induced more slowly.—It is probable, then, that the air when in contact with the living blood without its vessels may alter it a little, but the essential cause of death is still the same.

Hence it appears that the black blood either is not an excitant capable of keeping up the cerebral action, or that it acts in a deleterious manner, upon the brain. The injection by the carotid of various other substances will produce analogous effects.

I have killed animals in this way with ink, oil, wine, and water coloured with indigo. The greater number of the excrementitious fluids, such as urine, bile, the mucus of catarrhs, occasion death also by their simple presence on the brain. The serosity of the blood is fatal, but not as quickly so. Now it is certainly upon the substance of the brain, and not upon the internal surface of the arteries, that these different substances exert their influence. I have injected them all into the crural artery. In this way they are none of them mortal, but occasion always a torpor, amounting even to paralysis at times.*

* Active substances introduced into the veins can act on the organs in many ways at once. They have at first their peculiar action which is nearly uniform, whatever may be the mode of administration; but they produce also other effects resulting from their physical properties, and these last may vary according to the form in which they are introduced.

The substances introduced into the circulation have necessarily to pass through a double system of capillary vessels, and must consequently be very greatly subdivided. Hence we see that a viscid fluid would be unable to enter the smallest vessels, and that by remaining in those which can admit it, it will prevent the passage of the blood, and occasion a congestion either of the lungs or some other organ, according as it has been injected into a vein or an artery. A substance like quicksilver, which without being viscid, exhibits great cohesion among its particles, will produce precisely the same effects. The globules will never divide below a certain size. The air itself, mixed in a fluid such as the blood, will form bubbles which will divide with more diffi-

The black blood is doubtless fatal to the brain, the brain becoming at once a tonic from its presence. In what way

culty as they become smaller, and which can finally stop in the entrance of the capillaries, so as to prevent a free passage of blood in a part of these vessels. Boerhaave thought that it was always thus, by opposing a mechanical obstacle to the capillary circulation of the lungs, that air injected into the veins produced the death of the animal.

In an experiment in which I proposed to myself to change the nature of the blood by a foreign fluid, I injected into the jugular vein of a dog, an ounce of Olive oil, thinking that this substance would circulate without inconvenience with the blood; but it was not so, and the animal died in a few minutes after the injection.

In examining the organs after death, I saw that the oil had closed the last ramifications of the pulmonary artery, and that it had also stopped the circulation and respiration, by preventing the passage of the blood to the left side of the heart, by the pulmonary veins. An injection made with a thick solution of gum tragacanth produced precisely the same phenomena as the oil.

An inert, impalpable powder, suspended in water, immediately produces death, if injected into the jugular vein, because it shuts up the last divisions of the pulmonary artery.

If the injected substances are not divided at first in the blood, so as to spread uniformly into the different branches, death does not take place so quickly, because a part of the sanguineous canals remains free for the circulation. This is the case when we inject quicksilver or air in so small a quantity as not to produce instantaneous death. The congestion, in this last case, is often alone sufficient to produce it after a certain time; in the other case, there is added to the obstruction a real pneumonia caused by the presence of quicksilver in the obliterated vessels. We shall now relate four experiments of M. Gaspard, which will show the effects of the stagnation of this fluid in different organs.

"*First Experiment.* I introduced into the jugular vein of a small dog, four days old, thirty six grains of quicksilver purified through goat's skin. Soon after he refused to suck, lost his vivacity, motility and heat, had dyspnoea and fever, and died at the end of twenty four hours, having been all the time much colder to the touch than the other pups with whom he was. On opening the thorax, the lungs were found much inflamed, almost hepatized, heavy, puckered up and full of mercury."

"*Second Experiment.* I injected into the left carotid artery of a sheep, very near the brain, half an ounce of mercury with water; I does it act? I do not pretend to determine the manner; for this were only to begin a series of conjectures.

then tied with a double ligature the open vessel. The animal immediately manifested pain, and was for an instant immoveable, the head inclined, with stupor and a prominence of the eyes, which were extraordinarily open; then bending on the fore legs, twisting of the head and neck on the right shoulder, with a kind of stiffness or convulsive elasticity, which was always present till death, and returned, as by the effect of a spring, when I straightened the neck. Two hours after, standing impossible, state of drowsiness, some convulsive motions of the limbs, the left eye swelled, red and inflamed. The next day, the same state, almost total annihilation of the animal or external life, copious excretion of mucus by the left nostril, the eye still very large and inflamed. The third day, the same state; death took place fifty hours after the injection. On examination of the body it was found that the left eye was in a state of suppuration and contained mercury; the thyroid, pharyngeal auricular, lingual, labial, nasal and cerebral arteries of the left side, were admirably injected with this metal which run out under the instrument; but their capillary terminations contained none of it, and we could see to what ramification, to what sized caliber it had penetrated, and the point where it was unable to pass; the left nasal cavities exhibited a very pretty reticulated appearance, brilliant and silvery. Moreover all the organs of this side were red, inflamed and swelled by the presence of the foreign body, and it was curious to see the half of the thyroid gland, the tongue, the cheeks and the lips thus red and inflamed to the median line, whilst the other half was sound and pale; the left brain was slightly inflamed and especially the plexus choroides. Besides, I was unable to discover a globule of quicksilver in any of the other organs."

"*Third Experiment.* I forced with a pewter syringe into the crural artery of a large dog, a drachm and a half of quicksilver mixed with common water. The animal, immediately after the double ligature, did not manifest any sign of pain, and walked, bearing less on that limb, which was very sensibly cold, though not paralyzed. But about an hour after, he refused food, manifested by piercing cries acute pain, constant agitation, frequent change of place, and a very evident state of suffering; the limb soon ofter grew warm, became hot to the touch, with an obscure pulse under the tendo Achillis. This state of fever and pain continued the whole day and night. The next day, the limb was swollen and exhibited a phlegmonous œdema preserving the impres-

By this time we are authorised to conclude, that in asphyxiæ, the circulation which continues for some time

sion of the finger; the plantive cries were continual. On the third day his condition was still worse, and I then killed him from compassion sixty hours after the injection. I had carefully noticed the matter of the excretions, without discovering a particle of quicksilver in them. On examination of the body, I could not discover it in any organ, except the limb subjected to the experiment, which was swollen, inflamed and oedematous in all its textures; we observed abscesses in it of different sizes, containing quicksilver, pus, sanies and much gas, coming from the incipient gangrene of the parts; the metal usually occupied the centre of all the abscesses; the mercurial globules flowed out when I cut the skin, the cellular texture, the muscles and especially the small arteries, which were admirably injected by it; gelatinous exudations occupied the interstices of the muscles."

"*Fourth Experiment.* I injected a drachm of quicksilver, that had been passed through goat's skin, into the mesentric vein of a dog of middle size. The animal exhibited several severe symptoms which I shall not mention, because they probably depended on the opening of the abdomen and the inflammation that resulted from it; perceiving that they would become fatal, I killed him by another experiment, fifty two hours after the first. On opening the body, I found all the mercury in the liver; each globule was the centre of a small collection of pus, of which it was the cause; but the liver was but slightly diseased, but little inflamed, and only blacker and more gorged with blood than usual. The stomach contained an unusual quantity of very green bile; I could not discover any quicksilver in the other organs."

We see from all these different facts, that it is necessary for every thing that enters the circulation to arrive at it by very narrow channels, and after having been, as it were, sifted by the agents of absorption; this is one use of the absorbent organs that has not as yet been noticed. These facts also throw light on the properties of substances injected into the veins of animals, after having been dissolved in oil. We can believe that when these oily solutions are carried into the intestinal canal, they are not absorbed till after they have been gradually changed into a kind of emulsion, and we know that in this form fatty substances may be introduced with impunity into the circulation. We can in fact inject into the veins a large quantity of milk, and the portion of butter which is suspended in it, will not produce the effects which would necessarily result from it, if we injected this substance pure and only rendered liquid by heat.

after the interruption of the chemical functions of the lungs, interrupts the cerebral functions, from its being composed of black blood only. The fact is proved in another manner, for the movements of the brain continue to be made as usual.

If the cerebral mass be exposed, and the creature asphyxiated, the animal life will be extinguished, but the motion of the brain will be apparent still. Since then the latter cause of life subsists, the cause of death must be in the nature of the fluid, by which the organ is penetrated.

Nevertheless, if any affection of the brain coincide with asphyxia, the death which is occasioned by the latter, will be quicker than is usually the case. Strike a dog a violent blow upon the head, and then if he be deprived of air, he will die on the instant. In asphyxiating another animal already in a state of stupor, from compression of the brain, I observed that the vital functions were interrupted somewhat sooner, than when the brain is untouched during that operation; but the consequences hitherto deduced, may be supported by other experiments.

If in asphyxia the black blood suspend the action of the cerebral mass, it is evident that the black blood taken from the arteries of an animal dying of asphyxia, and injected into the brain of another, will be the cause of death.

The experiment will be found to succeed—cut the trachea, of a dog, and tie it up hermetically; then in the course of two or three minutes, open the carotid and receive into a syringe the blood, which flows from the vessels; inject it into the brain of another animal, and it will die.

The following experiment is very similar, but offers a somewhat different result. 1st. Adapt a tube with a stop-cock to the trachea of a dog, and a tube of silver to the carotid, next the head, after dividing this vessel, and tie up the extremity towards the heart. 2dly. Fix the other end of the tube to the divided carotid of another dog next the heart, and tie the extremity of the vessel towards the head. 3dly. Shut the cock of the tube in the trachea, and the black blood of the one dog in a short time, will be injected into the brain of the other.

The appearances above described will shortly afterwards succeed, but not so soon as in the former experiment, and if the transfusion be stopped, the animal which has been asphyxiated in this way, may recover and live. In the preceding experiment he will always die. It appears then that some extraneous pernicious principle is imbibed by the venous blood, when in contact with the air. Observe that for the latter experiment the dog from which the brain of the other is to be injected, must be stronger and more vigorous than the other. The reasons are evident.

I was desirous of trying whether the venous blood would not be capable of keeping up the cerebral action, if reddened artificially. For this purpose I opened the jugular and the carotid of a dog, and received the blood of the vein in a vessel filled with oxygen; it immediately became of a vivid purple, but on its injection into the brain, the animal was very suddenly killed. I was much surprised at this result, but ceased to be so on remarking, that a great quantity of air was mixed with the fluid, and that it arrived upon the brain, in a state of foam: now we know that a very small number of bubbles are sufficient to kill an animal, whether they be introduced on the side of the brain, or on that of the heart.

From this reflection, I was induced to repeat my experiments upon the injection of black blood, suspecting as I did that some small quantity of air might in these cases have been contained in the extremity of my syringe. I soon however recollected that if this cause were real, it should produce the same effect in every instance whatever were the fluid employed, now when water is injected there is nothing of the kind observable.

We may be thus assured that the black blood is either incapable of keeping up the action of the brain, or that it acts in a deleterious manner upon that organ, from the very nature of the principles, which it contains. From such datum it should appear that the life of the asphyxiated person might be restored, by pushing on into the brain a sufficient quantity of arterial blood, but here we must make a distinction of two periods in asphyxia: 1st. That in which the cerebral functions are only suspended: 2dly. That in which the circulation and the movements of the breast are stopped (for this disease is ever characterised by the sudden loss of all animal life, and consecutively by that of the organic life.) Now, as long as the first period of asphyxia continues, I have observed that, by the transfusion of red blood into the brain, from the heart of another animal, the movement of the creature which is dying will be restored by degrees, and the cerebral functions resume in part their activity; but this is only a temporary thing, and the animal will fall again into its previous dying state, if the asphyxiating cause be continued

On the other hand, if during the first period, to which we have alluded, the air be readmitted, into the trachea, the lungs will be reanimated, the blood be coloured, and the creature be revived without the assistance of any transfusion; and such transfusion again is of no avail, after the second period of asphyxia, so that this experiment offers only a proof of what we already know; with respect to the difference of the influence of arterial and venous blood upon the brain, and not a remedy in case of asphyxia.

Again, whenever I have injected venous blood into the brain, by the help of a syringe, I have universally found that such proceeding is fatal. Though the cause of asphyxia be removed, and arterial blood injected, either with the syringe, or immediately from the heart of another animal, it is of little effect, and frequently of none whatever. And in general asphyxia when produced by blood, which has been taken from the venons system itself and pushed into the brain is much more certain and more decided, than that which is occasioned by ligature of the trachea, or the introduction of different gases into the lungs.

After having established by different experiments, how fatal the influence of the black blood is upon the brain, which receives it from the arteries whenever the chemical functions of the lungs are suspended, it will not be amiss or out of place to shew, that the phenomena of the asphyxia, which are observed in the human subject, accord with the experiments of which I have given the detail.

1st. It is generally known that every kind of asphyxia affects the brain in the first instance; that the functions of this organ are the first to be annihilated; that the animal life, and particularly the sensations cease; that all our relations with exterior objects are instantly suspended, and that the organic functions are only consecutively interrupted. Whatever be the mode of asphyxia, by submersion, strangulation, gases, or a vacuum, the same phenomena occur at all times.

2dly. It is known that the greater number of those who have escaped suffocation, have been sensible only of a general stupor, the seat of which has been evidently in the brain. It is known also, that death is almost always certain in these cases, while the pulse and the heart have ceased to be felt.

3dly. It is affirmed by almost all such persons as have survived this accident, especially when caused by the vapour of charcoal, that the first thing of which they were sensible, was more or less pain in the head, an effect in all probability occasioned by the first influx of the black blood into the brain. This fact has been noted by the greater number of authors, who have written on asphyxia.

4thly. The vulgar expression that "charcoal flies to the head" is surely a proof that the brain, and not the heart, is the first affected in the asphyxia occasioned by this deleterious substance. The unprejudiced vulgar, oftentimes observe more correctly than we do, who frequently see only what we wish to see.*

5thly. There are many examples of persons, who after escaping the pernicious effects of the vapour of charcoal, have been subject afterwards to paralytic affections, and loss of memory. Such changes have evidently their seat in the brain. Convulsion also is frequently the effect of the impression of mephitic vapour: head-ache is a common symptom, and for the most part remains after the others have disappeared. In every book of cases may be seen examples of these affections.

In cold-blooded animals, and in reptiles especially, this influence of the black blood on the brain, though real, is

* Is it true that common people observe without prejudice? Have they not, on the contrary, on several physiological and pathological phenomena deeply rooted prejudices? It is besides a very singular idea to wish to judge by the name which they give to an affection, of the organ primarily affected. If we always reasoned in this way the expression of *sick at heart* which is given to nausea, would assign to vomiting a wholly different nature from what would be correct.

much less apparent. Make an incision into both sides of the breast of a frog, then tie the lungs at their root, and the animal will live notwithstanding for a considerable time. Cut away the lungs entirely, and the same phenomenon will be remarked. In fish, the relation between the lungs and the brain, is somewhat more direct, for by the organization of the branchiæ, they differ essentially from reptiles. I have taken away the cartilaginous plate which covers the gills of the carp, the motion of the gills however continued to be made as before, and the animal lived without any apparent injury done to its functions. I afterwards put a ligature about the cartilaginous rings which sustain the branchiæ, so as to hinder all motion in the pulmonary apparatus. The effect was, that the animal languished, his fins dropt, his muscular movements soon grew weak, then ceased entirely, and the creature in the course of a quarter of an hour was dead. The same phenomena with some little variety, were observable in a carp from which I cut away the branchiæ.

After all however, the particular nature of those relations, which unite the heart, the lungs, and the brain, both in the red and cold-blooded animals, is well worthy the farther investigation of physiologists. The latter sort of animals, can neither be subject to syncope or apoplexy, or at least the character of these diseases must be very much modified in them. They are with much more difficulty asphyxiated. We shall now return to those species which bear a nearer resemblance to man.

From the influence of the black blood over the heart, the brain, and the rest of the organs, it was my opinion, that persons affected with varicose aneurisms, would perish less quickly from asphyxia then others; because the red blood passes into the veins, and traverses the lungs without requiring alteration. Accordingly, it should be capable of keeping up the cerebral action.

To be assured if this suspicion were well founded, I made a communication between the carotid artery and jugular vein of a dog, by means of a curved tube. The pulsation of the artery was thus communicated to the vein. I afterwards asphyxiated the animal by stopping the trachea, but the phenomena of death were little different from those of common asphyxia.

We may conclude with certainty, from the various considerations and experiments presented in the present chapter.

1st. That when the chemical phenomena of the lungs are interrupted, the black blood acts upon the brain, as it does upon the heart, by penetrating the tissue of that organ, and depriving it of the excitement, which is necessary to its action.

2dly. That its influence is much more rapid upon the first, than on the second of these organs.

3dly. That it is the inequality of such influence, which occasions the difference in the cessation of the two lives in the case of asphyxia. The animal life is always annihilated before the organic life.

We may conceive from what has been said in this and the preceding chapter, how unfounded are the suspicions of those who have supposed that the brain, after the separation of the head from the body by the guillotine, might live awhile and have sensation. The action of this organ is immediately connected with its double excitements.—1st, By motion; 2dly, By the nature of the blood which it receives. Now, when the interruption of such excitement is sudden, the interruption of every kind of feeling must also be sudden.

When the chemical functions of the lungs are suspended, the disturbance induced in the functions of the brain, has indeed a very considerable influence on the death of the other organs; nevertheless, such disturbance is the beginning of death only in the animal life, and even then is connected with other causes. The organic life ceases from the sole presence of the black blood among the different organs. The death of the brain is only an isolated and partial phenomenon of asphyxia, which does not take place in any particular organ, but in all alike. We shall explain this assertion in the following chapter.

CHAPTER VIII.

OF THE INFLUENCE OF THE DEATH OF THE LUNGS OVER THAT OF THE ORGANS IN GENERAL.

I HAVE just shewn in what way the interruption of the chemical phenomena which take place in the lungs, annihilates the functions of the heart and brain. It remains me to shew, that the other organs of the body are as much affected by such cessation; so that asphyxia, as I have said, is a general disease, and not an affection of any one organ in particular.

But before I proceed to analyze the effects of asphyxia upon the organs in general, and consequently the mode of action of the black blood upon them, it may be of use to explain the phenomena of the production of this kind of blood, at the instant when the functious of the lungs are suspended. This paragraph will possess, perhaps, some interest; it might have belonged indifferently to either of the preceding chapters.

1. *Exposition of the phenomena of the production of black blood, when the chemical functions of the lungs are suspended.*

It is known in general, that the blood is coloured in traversing the lungs, that from black it becomes red; but this very interesting fact, has not been hitherto the object of any precise or rigorous experiment. The lungs of the frog, of which the air vessels are large, and the membranes thin and transparent, would serve very well for the purpose of observing the process of the phenomenon in question, but for the slowness of respiration in these animals, the difference of organization in their lungs, and the too small quantity of blood by which they are traversed. On such account there can be little analogy between them and the more perfect animals, and then again our experiments upon these little amphibiæ, are all of them rendered incomplete, by the tenuity of their pulmonary vessels, and the impossibility of observing the correspondence of the change of velocity in the circulation, with the colour of their blood.

The phenomena of the respiration of man, and those of the functions which are dependent on it, can be illustrated only by experiments made upon animals with a double ventricle, with a complete pulmonary apparatus, possessed of a temperature superior to that of the atmosphere, and the two separate systems of venous and arterial blood; but on the other hand, in the mammalia resembling man, their respiratory apparatus, the thickness of the vessels and cavities of the heart, impede the view of the blood which they contain; and experiments made without an absolute inspection of the fluid there, can only give us approximations. The indecisive experiments of former physiologists on this subject were my motives for the present inquiry.

One of the best methods of judging of the colour of the blood, consists as I have often said, in fixing a tube with a stop-cock to the trachea. By this, the influx of air into the lungs, may be regulated or altogether stopped. By this, we may distend the organ, or entirely evacuate it; it gives us also the facility of introducing whatever gas we please. The animal breathes very well by such pipe when it is open, and would live with it for a considerable length of time without any very great alteration in its functions.

In the second place, an artery, the crural or carotid for instance, must be opened with the view of observing the varieties of colour in the blood projected from it. A small artery should not be chosen. From such a one the course of the blood would be suspended by the slightest accident; and on the other hand, the larger arteries expend in a little time too large a quantity of blood; this inconvenience may be remedied, by adapting to these vessels a tube of a small diameter, or a stop-cock.

All things being thus prepared, on a dog, for instance, let us see what are the phenomena which take place, when the colour of the blood is altered. In my indication of these, however, I shall speak only of what I have seen, and by no means pretend that in man their duration should be similar or uniform, or even that in animals of the same species, under the different circumstances of sleep, digestion, exercise, and passion, &c. if it were possible in such way to repeat them, they should be alike. The instability of the animal functions, as I have said, is extreme; they cannot be submitted to calculation; they remain indeed the same, but their variations as to plus or minus are innumerable.

Let us now return to our subject :

1st. If the cock of the pipe be shut immediately after the animal has inspired, the blood begins to be altered in colour at the end of about thirty seconds.—At the end of a minute its colour is dark ; at the end of a minute and half or two minutes, it is perfectly similar to venous blood.

2dly. If the cock of the pipe be shut immediately after the animal has expired strongly, the blood receives its tinge of black some seconds the sooner.

3dly. If the air of the lungs be pumped out entirely with a syringe, the blood will suddenly pass from red to black.* In such case it appears that the artery immediately throws out a black stream, after it has expelled the red blood which it previously contained. There is no gradation. The blood is expelled by the arteries, such as it is in the veins.

4thly. If, instead of making a vacuum in the lungs, we inflate the air cells to the full, the blood is a longer time in becoming black, a minute at least, and is not completely black before the end of three minutes.—This will vary according to the quantity of air injected.

From all these experiments it follows, 1st, That the length of the interval, during which the blood retains its red colour, is in direct proportion to the quantity of air contained in the lungs ; 2dly, That as long as there remains any quantity however small of respirable air in the cells of the lungs, the blood will preserve more or less of its crimson colour ; 3dly, That this colour diminishes in proportion as the respirable air diminishes ; and

* It is not possible to remove by this means a great portion of air contained in the lungs, for the last ramifications of the air-tubes being flexible, their parietes soon come in contact, and thus oppose the exit of the air contained in the bronchial cells.

4thly, That the blood is exactly similar to that of the veins, as soon as the whole of the vital air in the extremities of the bronchiæ has been exhausted.

In my different experiments with regard to asphyxia, I have remarked, that if after shutting the cock of the syringe, the animal agitate the chest by similar movements to those of inspiration and expiration, the blood is a longer time in losing its red colour, than in the case where the breast remains at rest. Such motion and agitation must cause a circulation of air in the cells, in consequence of which, a greater number of its points must be presented to the circulating fluid. My experiments which I shall presently detail on the breathing of animals in bladders, will prove the truth of the above explanation.

At present I pass to a contrary set of phenomena—to those which are exemplified when the blood regains its arterial colour during the period, which, from a state of asphyxia, restores the animal to life.

1st. When the cock, which for some minutes has been shut, is opened, the air immediately penetrates into the bronchiæ; but previously the animal expires strongly. Six or seven large inspirations and expirations follow each other precipitately. The artery being now examined, a jet of a very vivid colour is seen succeeding to the efflux of black blood, and takes place in thirty seconds at most, from the time of opening the tube. This is the inverse of the phenomenon above described. There are no successive shades perceived from black to red; the passage is instantaneous. The brightness of the colour seems even to be greater than is natural.

2dly. If instead of suddenly turning the cock, a very strong stream of air only be admitted, the colour is less lively indeed, but just as quickly regained.

3dly. If there be adapted to the stop-cock a syringe full of air, and this fluid be pushed into the lungs, on opening the pipe, and then the pipe be suddenly shut again, the blood will become red, but much less evidently so, than when the entrance of the air is owing to voluntary inspiration. Here the portion of air injected must repel into the bottom of the cells whatever is already vitiated, while on the contrary, if the tube be simply opened, the vitiated air is at once rejected, and then replaced from without. The following experiment appears to confirm this idea.

4thly. If instead of pushing air upon that which is contained in the lungs, we pump out the vitiated air in the first place, and then inflate the organ, the colouring process will be more rapid, and the colour of the blood itself especially, more lively than in the preceding case, though less so than in the first of this latter suite of experiments.

5thly. The lungs being exposed on both sides by a lateral section of the ribs, the circulation will continue to go on for a certain time. Now, if by means of a syringe adapted to the stop-cock in the trachea, the pulmonary vesicles be alternately emptied and dilated, the changes from red to black, and from black to red, will be observed as in the above experiment, as long as the circulation lasts.

The following consequences may be inferred from the facts, which I have mentioned.

1st. The rapidity with which the blood becomes red again, on opening the pipe in the trachea, is a plain proof, that the principle from which this colour is gained, must pass into the blood across the membranous parietes of the air cells, and not by means of the absorbents. I shall establish this fact hereafter upon other proofs.

2dly. The celebrated experiment of Hook, in which the enfeebled movements of the hearts of animals in a state of asphyxia are accelerated by injecting air into the lungs, is very well explained. The red blood penetrates into the fibres of the heart, and puts an end to the debility induced, by the influx thither of the black blood.

3dly.. I do not believe, that motion can ever be restored to the heart, when once it has been wholly annihilated by the presence of venous blood. In this I have never succeeded, though I have often attempted it. Many authors, however, pretend to have done so. If the heart be reanimated by arterial blood, it is necessary at any rate, that such blood, should pass into it, now in what way can it arrive there, if the circulation have entirely ceased.

We must observe, however, that there are two cases of interruption in the action of the heart from asphyxia. Sometimes there supervenes a syncope which arrests the movement of this organ, before the black blood has been able to produce such effect; and here it is manifestly capable of excitement, from the presence of the red blood, just as it is from the application of any irritating cause; but when it has been injected with venous blood, it then contains within itself the principle of its inertia, which can be removed only by the contact of arterial blood with it; but such contact is become impossible.

I was very desirous of knowing what the influence might be of the different gases when inspired upon the colour of the blood. Accordingly I successively adapted to the pipe different bladders, containing hydrogen and carbonic acid gas.

The animal alternately swells and cantracts the bladder by the different motions of the thorax. It is calm at first, but at the end of three minutes, begins to be agitated; its respiration is now hurried and embarrassed, and at the end of four or five minutes, the blood of the carotid is black.

Whichever of the two gases be employed, there is little difference in the above phenomena. This remark should be compared with those of the Members of the Institute, who have assured us that complete asphyxia supervenes only after an interval of ten minutes, with pure hydrogen, and at the end of two minutes with carbonic acid gas. The black blood must continue, therefore, to circulate for a longer time in one than in the other kind of asphyxia here spoken of. This circumstance confirms some reflections which I shall have occasion to offer upon the difference of asphyxiæ.

For what reason should the blood be a longer time in losing its colour, when bladders of non-respirable air are fixed to the pipe, then when the cock is simply turned? The reason of this is evident. By the different motions of the lungs, the air is expelled and reabsorbed, the respirable portion of it must consequently be successively presented to the capillary orifices, by which it is transmitted to the blood.

On the contrary, when the pipe is simply shut, the air it is plain has not the same influx and efflux; in comparison with such motion, it may be said to stagnate so that the respirable portion of that which is enclosed in the bronchial cells is exhausted, and the blood ceases to be coloured, though there remain in the trachea and its larger divisions, a considerable quantity of fluid, which has not been despoiled of its vivifying principle. Of this we may be certain, after the death of the animal, by cutting the trachea under the pipe, and plunging a bougie into it. The process by which the blood gains its red colour appears to take place only at the extremities of the bronchiæ, the inner surface of the larger aerial vessels, has nothing to do with this phenomenon.

We may convince ourselves of the reality of the explanation which I have offered, if we pump out the air of the lungs, before we fit the bladder to the trachea; for in such case, the animal must breathe the air of the bladder without mixture. Here the change of the blood to black is almost sudden, but here also, as in the preceding experiment, there is little difference in the phenomena, whatever gas we employ. I have chosen the two gases above mentioned, because they enter into the phenomena of natural respiration.

When we adapt to the pipe a bladder full of pure oxygen, the blood is very long in becoming black, but does not at first assume a redder tint than it usually has.

II. *The blood which has been blackened in consequence of the interruption of the chemical functions of the lungs penetrates into the organs, and circulates for some time in the vascular system of the red blood.*

We have just established what are the phenomena of the alteration of colour in the blood, when the chemical functions of the lungs are suspended. Before we consider the influence of this change upon the death of the organs, let us prove, that they are really penetrated by the blood when so altered.

I have proved it to be a fact, that the force of the heart subsists for some time, notwithstanding the influx of the black blood into it, and have shewn that the black blood is thrown out with a jet, similar to that of the red blood, &c. &c. Hence I might already conclude, 1st, That the arterial circulation continues for a certain time, though the arteries contain a fluid, to which they are not accustomed, and 2dly, That the necessary consequence of such circulation, must be the injection of the different parts of the body with black blood; but we shall deduce the latter conclusion from precise and rigorous experiments. To be certain of this important fact, we have only to expose successively the different organs, while the animal is suffering a death of asphyxia. I have in this way examined the muscles, the nerves, the membranes and the viscera. The following are the results of my observations.

1st. The colouring matter of the muscles, exists in the body in two states—at liberty, or in a state of combination; in the vessels, where it circulates with the blood, or in the fibres, with which it is combined. It forms especially the colour of the muscles, and in such state undergoes no alteration from asphyxia; in its free state it is blackened. The divided muscles furnish an infinity of black drops, which are no other than indices of the divided vessels. Such drops contrast with the red of the muscles; but when circulating within them, are the cause of that livid tin which they then present.

2dly. The nerves are habitually penetrated by a number of small arteries, which creep along within their tissue, and carry to them both excitement and life. In the state of asphyxia the black blood by which they are traversed, is announced by the dull brown, which succeeds to the rosy-white, which is natural to them.

3dly. There are few parts, where the influx of the black blood is more visible, than in the skin; the livid spots so frequent in asphyxia, are only the effect of the obstacles which it meets with, in its passage towards the general capillary system, to the organic contractility of which it is not a sufficient excitant. To this cause also is owing the tumefaction of certain parts, such as the cheeks and lips. This phenomenon we have seen already in the lungs, they cannot be traversed by the blood and therefore become in the last moments of life, the seat of a fulness, which affects the whole of the capillary system there; but for the reasons, which I have assigned, such fulness is always more evident in the capillary system of the lungs, than in that of the system in general.

4thly. The mucous membranes also, when the chemical functions of the lungs are interrupted, exemplify a similar phenomenon. The swelling of the tongue, observable in those that have been drowned or hanged, or asphyxiated by the vapour of charcoal, the lividity of the membrane of the mouth, of the intestines, and the bronchiæ which have also been remarked, depend on no other cause. The following is a proof of this assertion:

Drag out of an animal a portion of the alimentary canal and divide it in such way as to expose its inner surface. Then shut up the pipe which has been previously adapted to the trachea, and at the end of four or five minutes, a brown tint will succeed to the red one, which is natural to this surface.

5thly. I have made the same remark upon the fleshy granulations of a wound, inflicted on an animal, for the purpose of observing the manner in which they are coloured by the black blood. In the two last experiments, this phenomenon is slower in taking place than in many other circumstances.

6thly. The alteration of colour in the serous membranes is much more quickly effected than it is in the mucous membranes. Of this we may assure ourselves by comparatively examining the outer and inner surfaces of the intestines, while the pipe in the trachea is shut; in the serous membranes, the livid tint which they assume, depends upon the vessels, which creep underneath them, and not on the blood by which they are penetrated. Now as these vessels are considerable, the black blood must flow into them almost as soon as it is produced. In the mucous membranes on the contrary, and in all cicatrices, the colour which they take on in asphyxia, is made by the capillary system of the membrane itself, which system is much more tardy than the other, to receive the black blood, and to be penetrated by it ; so much so indeed, as to refuse it in some parts. I have many times seen the membrane of the nasal fossæ very red in asphyxiated animals, while that of the mouth has been quite livid, for there are parts into which as I have said the black blood will not penetrate at all, and then they preserve their natural colour. 2dly. There are others into which it evidently passes, but where it stops, and then a simple change of colour is observed, if it have penetrated but in small quantity ; and again, if it have penetrated in a considerable quantity, together with such change of colour, there will be observed a tumefaction of the part. 3dly. In other cases, the black blood merely traverses the parts, without stopping in the capillary system, and passes at once into the veins, as the red blood does.

In the first and second case, the general circulation experiences an obstacle which puts a stop to it in the general capillary system. In the third, which is much more universal, it is in the capillaries of the lungs that the blood is at last arrested, after having circulated in the veins.

These two sorts of impediment coincide with each other, in many instances. Thus in asphyxia, a part of the black blood which circulates in the arteries stops in the face, upon the mucous surfaces, in the tongue, and in the lips, while the other, and much the larger quantity, finds no impediment in the general capillary system, and is finally arrested in the lungs.

What is the reason, why certain parts of the capillary system refuse to admit the venous blood, or if they admit it, do not pass it on to the veins; while others are less enfeebled by it, and transmit it as freely as ever. All this must certainly depend on the relation existing between the sensibility of each part and the venous blood.

I was desirous of making use of the power, which we possess, of changing the colour of the blood, for getting some insight into the influence of the circulation of the mother, upon that of the fœtus; accordingly I procured a bitch big with young, and asphyxiated her, by closing a tube, adapted to the trachea. About four minutes after she had ceased to breathe, I opened her; the circulation was going on. I then cut into the matrix, and exposed the cord of two or three of the fœtuses. The artery and the vein, were both of them full alike of venous blood.

Had I been able to procure other bitches in a similar state, I should have repeated this experiment in another manner. I should in the first place have compared the natural colour of the vein, with that of the artery. In many of the young of the guinea pig, the difference appeared to me to be much less than it is in the adult animal. In many circumstances indeed I could perceive no difference whatever. Both the arterial and venous blood were equally black, though the respiration of the mother was in no wise impeded by the opening of the belly. Secondly, I should have closed the tube in the trachea, and then have observed whether the change in colour of the umbilical artery of the fœtus (supposing the blood of the artery to be different from that of the vein) were correspondent with that, which would inevitably take place in the blood of the mother. Experiments made with a view to these circumstances, and on large animals, might probably throw much light upon the mode of communication, between the mother and the fœtus. Observations are also much to be desired, with respect to the colour of the blood in the human fœtus, and the cause of its passage from a livid colour, to the very marked red which it assumes, some little time after birth.*

I might add a number of examples to these, which I have already related of the blackening of the organs by the venous blood. Thus, the kidney of a dog exposed, while the animal is dying of asphyxia, is much more livid than in its natural state, the spleen also and the liver, when divided, emit only black blood, instead of that mixture of red and black blood which is observable, in the section of these organs, upon an animal which breathes freely.

But I trust that we have facts enough to establish it as a certainty, 1st, That the black blood after the interruption of the chemical functions of the lungs, continues for some time to circulate, and 2dly, That it penetrates into the organs, where it replaces the red blood; these circumstances explain the reason, why on opening the body we always meet with black blood even in the vessels which are destined for the circulation of arterial blood.

In the last moments of existence of whatever death the individual may have died, we shall always observe the lungs become embarrassed and cease to perform their office, for some time previous to the total suspension of the functions of the heart. The blood makes its circle through the system, after ceasing to receive the influence of the air, and consequently in its venous state; accordingly it must remain so in the organ in every case, although

* These observations have been made on the great mammalia, and there has not been remarked any difference of colour.

the circulation be much less evident, than in asphyxia, for it is in this circumstance that consists, the great peculiarity of asphyxia. The following phenomena may now be easily understood.

1st. When the left auricle and ventricle together with the large divisions of the aorta, on opening the body, are found to contain blood, such blood is always black. The fact is familiar to those who are in the habit of dissecting. In exercising my pupils on the surgical operations, I have always observed that when the open arteries are not entirely empty, their contents are composed of venous blood.

2dly, The corpus cavernosum is always gorged with this sort of fluid, whether flaccid or in a state of erection. For I have seen it in the latter state in two subjects brought to my amphitheatre. One of these men had hanged himself, the other had died of concussion of the brain.

3dly, The blood which is found in the spleen is never red; but sometimes on the exterior, and sometimes on the concave surface of this organ, I have observed spots of a scarlet colour, for which I cannot account.

4thly, After death, the mucous membranes lose the red colour by which they are characterized during life. They assume a black and livid hue.

5thly, Blood extravasated in the brain of persons in a state of apoplexy, is almost always found to be black.

6thly, Sometimes, instead of accumulating inwardly the blood injects the surface of the body. In such case the face, the neck, and shoulders swell, and are infiltrated with blood. I have frequently remarked this sort of phenomenon in the subject, but have never found it coincide with any internal extravasion.—The colour of the skin is then of a purple or deep brown, an evident sign of the sort of blood with which it is injected, and is evidently produced by the stagnation of the black blood in the external capillary system, not by the reflux of the blood from the veins.

I shall not dwell any longer upon the numerous consequences of the above established principle. I shall only observe, that when death commences by the circulatory system, the preceding phenomena are not to be remarked, or at least very little perceptible.

Let us now pass on to the influence of the black blood upon the organs of which it penetrates the tissue.

III. *The black blood which penetrates the organs, as soon as the chemical functions of the lungs have ceased, will not maintain them in a state of life and activity.*

To determine what the influence of the black blood is upon the organs, I shall first remark, that the property of the red blood is to stimulate them, and keep up their vital actions. This will be proved by the following observations:

1st, Compare phlegmon, erysipelas, and inflammatory tumours (to the formation of which the red blood is essentially requisite) with scorbutic spots, and petechiæ, produced by the black blood. The first will be found connected with the exaltation of the vital powers, the second with their depression.

2dly, Examine two men, the one with a rosy coloured skin and large breast, announcing vigour of lungs, the other with a pale and sallow countenance, and narrow chest: in these the vigour of the chemical combinations which are made in the lungs, should certainly be very different.

3dly, The greater number of gangrenes in old men, begin with a lividity in the part, a lividity which is evidently the index of the absence or diminution of the arterial blood in the part.

4thly, The redness of the branchiæ of fish is always the sign by which their vigour may be recognised.

5thly, The redder the granulations of wounds, the more healthy is their nature; the paler or browner they are, the less has the part a tendency to cicatrise.

6thly, The lively colour of the face, and the ardent eye, coincide with the energy of the cerebral actions in certain fevers.

7thly, The more developed the pulmonary system of animals, the more active are the chemical processes of the lungs, and the more developed and perfect the general life of their different organs.

8thly, Youth, which is the age of vigour, is that also when the red blood predominates in the system. The arteries of old people are smaller, the veins larger than those of the young. It is a fact universally known, that at the two extremities of life the proportions of the two vascular systems are inverted.

I am ignorant of the manner in which the red blood excites and keeps up the life of the parts. Perhaps the principles by which it is coloured become combined with the different organs to which it is distributed. In fact there is a considerable difference between the phenomena of the general and those of the capillary system.

In the first, the blood in changing its colour, leaves behind it the principles which made it red; in the second, the elements to which its blackness is owing, are rejected by respiration and exhalation. Now, this union of the colouring principles of the arterial blood, may probably constitute a material part of the excitement which is necessary to the action of the organs.—If such be the case, the black blood as it does not contain the materials of such union, cannot act as an exciting cause. This idea, however, I offer only as a probability, and am by no means prepared to defend it as a truth; it may be ranked on a par with that of the sedative action, which I have said may be excited by the black blood on the different parts—for, however probable an opinion may appear, there should be no real importance attached to it as an opinion only.

Without regard then to any system, let us inquire how the black blood, from its contact with the various parts, is the occasion of their death; how it acts on the parts of the animal life, and how it acts on those of the organic life.

All the organs of the animal life depend upon the brain; now, we have seen that the black blood paralyses the cerebral powers almost suddenly. In the state then of asphyxia, the locomotive, the vocal and sensitive organs, must be inactive. From the same cause, their exercise must be suspended in all those different experiments where black blood is injected into the brain, the other parts receiving the red blood as usual. But when the black blood circulates throughout all the system, when the whole of the organs, as well as the brain, are submitted to its influence, then there are two other causes of death connected with those which have been mentioned.

1st, The nerves, which are penetrated by it, for that very reason are no longer capable of keeping up the communication between the brain and the senses on the one hand, and on the other, between this same viscus and the locomotive or vocal organs.

2dly, The contact of the black blood with these organs themselves annihilates their actions. Inject the crural artery of an animal with the black blood taken from one of its veins, and the movements of that member will be shortly afterwards enfeebled, or wholly paralyzed. In this experiment, the upper part of the artery, for manifest reasons, should be that to which the pipe of the syringe should be fixed.

I am aware that as to this experiment, it may be asserted that the ligature of the artery, of itself, is capable of paralyzing the limb. In fact, such circumstance has happened twice with me, but I have also had occasion to observe, that it does not necessarily follow the ligature of this vessel, as it does the ligature of the aorta : when the latter vessel is tied, all movements cease at once ; notwithstanding all which, the result of the injection of black blood, is almost constantly that which I have asserted it to be ;—I say almost, 1st, Because I have once seen it fail in its effect, though done with the requisite precautions ; 2dly, Because the debility, which is induced, both in duration and degree, will be according to the strength of the animal on which the experiment is made.

There is also occasioned in this experiment, a manifest suspension of the sensibility of the animal ; it is not indeed so ready to appear as the loss of motion ; but it always comes on, especially if the injection of the black blood be repeated three or four times, with small intervals.

A similar, but a more tardy effect may be produced by adapting to the canula, which has been placed in the crural artery of an animal, a tube which has been previously fixed to the carotid of another animal, and then by asphyxiating the latter.* The organs of the internal

* The difference that is remarked in the results of this experiment, compared with that in which the venous blood is introduced by means of a syringe, arises probably from this, that in the first the blood that is forced into the artery has already begun to coagulate.

life are not dependent on the brain, and therefore are not affected by the suspension of the cerebral action in asphyxia. It is the influx of the black blood which is the immediate cause of their death.

I have already demonstrated what the influence is of this blood upon the organs of the circulation. We have seen how the heart ceases to act, as soon as it is penetrated by it; it is owing in part to the injection of the arterial and venous parietes themselves, by the vasa vasorum, that the vessels are forced to suspend their actions.

It will be always a difficult thing to prove, that the secretions, the exhalations, and the process of nutrition, could not be made from venous blood, because the circulation of this sort of blood in the arteries, does not continue for a sufficient time, to allow of observations, or the manner in which these functions would be affected by it. On this subject, however, I have made some essays. 1st, I exposed the inner surface of the bladder of a living animal, after having previously divided the symphysis pubis, and opened the lower belly, I then examined the oozing of the urine from the orifices of the ureters, while I asphyxiated the animal. 2dly, I divided the vas deferens, with the view of observing, whether the semen would flow or not, during such state.

In general, I have had occasion to remark, that during the circulation of the black blood in the arteries, no fluids appear to issue from the different secreting tubes. But I confess, that in all these experiments, and in other similar ones which I have made, the animal is too much agitated, and the limits of the experiments too circumscribed, for any thing like a well founded judgment to be formed on the subject in question. It is chiefly from analogy, then, that I am led to conclude, that the black blood is unfit for the purposes of exhalation and nutrition; such supposition also accords well with divers of the phenomena of asphyxia.—1st, The want of exhalation from the skin during the state of asphyxia, is probably the reason of the phenomena of the animal heat in such sort of death.* 2dly, In asphyxiating animals very slowly during digestion, I have uniformly observed, that the bile ducts, and duodenum, contain a much less quantity of bile, than they do at such time, when these parts are exposed in the living animal.—3dly, As the blood loses nothing from the exercise of these functions, it must of course accumulate in the vessels; and in fact it is very fatiguing and unsatisfactory, to dissect the bodies of those who have been hanged or asphyxiated with the vapours of charcoal, from the fluidity and abundance of their blood. But this abundance, perhaps, may depend upon the weakness of the absorbents. In other sorts of death, the absorbents continue for some time to act upon the serous portion of the blood remaining in the vessels. In asphyxia there is neither secretion nor absorption.

The excretions also appear to be affected much in the same way. The bladder of asphyxiated persons has been observed by Portal, to be very much distended. Such distension, no doubt is occasioned by the urine already secreted before the accident which was the cause of their deaths. In general, the asphyxiæ which are occasioned by the circulation of the black blood unmixed with any deleterious substance, are not accompanied with those spasms, which in so many other sorts of death, are so

* The deficiency of cutaneous exhalation in the last moments of life may contribute a little perhaps to the preservation of animal heat; but we have shown that there are other more powerful causes for this phenomenon. This deficiency of exhalation united to the inaction of the secretory organs, in the very short period in which the black blood runs in the arteries is an altogether insufficient cause to explain the abundance of blood that is found in the vessels of those who have died of asphyxia.

frequent. These spasms, which evacuate the organs of their fluids, should be carefully distinguished from the simple relaxations of the sphincters, by which analogous effects are produced.* In asphyxia, all is debility, in asphyxia, we never see that augmentation of life, that development of power, which so frequently mark the latter movements of the dying.

Hence also perhaps, the great flexibility of the members of asphyxiated persons. The stiffness of the muscles appears to depend in many cases, on the circumstance of death having come on precisely at the moment of their contractions. The fibres remain approximated, and coherent among themselves;† in asphyxia, on the contrary, as there exists an universal relaxation and want of action in the parts, they remain so after death, and yield to whatever impulse may be communicated to them.

I confess, however, that this explanation is subject to a difficulty which I cannot solve. Persons asphyxiated by mephetic vapours, perish nearly in the same way as those who are drowned; if the cause of their death be different, its effects are the same, as may be seen by opening the carotid of two dogs at the same time, that into the lungs of the one are injected the vapours of charcoal, and into those of the other, a certain quantity of water, which water, as in the drowned, is soon reduced into a state of foam.

* This is not an uniform fact, and it is even very common to find, in persons who have been hung, the bladder completely empty.

† The moment respiration ceases, and the source of heat is consequently cut off, it is not astonishing that an animal body should become cold quicker in water then in a much less dense fluid, like the air. It should also be remarked that the water, on account of the evaporation that takes place on its surface, has almost always a temperature below that of the surrounding air.

Notwithstanding this similitude of the last phenomena of life in the two cases, the members in the first remain for a certain time warm and supple, while those in the second, especially if the body be plunged into water during the experiment, become very suddenly stiff and frozen. Let us return, however, to our subject. We may conclude from the various facts and considerations related in this chapter, 1st, That when the chemical functions of the lungs are suspended, the functions of all the other organs are suspended also, from the presence of black blood within their substance. 2dly, That the death of the organs in general, coincides with that of the brain, and the heart, but is not immediately derived from them. 3dly, That if it were possible for the brain and heart to receive an influx of arterial blood, while the others were dying, from that of the venous blood, they would doubtless continue to exert their accustomed actions. 4thly, That, in a word, asphyxia is a general phenomenon, developed at the same time in all the organs, but especially in one of them.

From this manner of regarding the influence of the black blood upon the different parts of the body, it appears that death is very soon the result of its circulation in the arteries. Nevertheless, certain organic defects have sometimes prolonged after birth, the mixture of the two sorts of blood, a mixture which is known to be made in the fœtus. Such was the malconformation mentioned by Sandeford, in a child, the aorta of which arose by a branch from each of the ventricles. Such also appears, at first sight, to be the opening of the foramen ovale in the adult.

We shall remark, however, that the existence of this foramen, does not suppose the passage of the black blood into the red-blooded auricle, as is generally believed.

For the two semi-lunar valves, between which it is situated when met with after birth, are necessarily applied to each other by the pressure which the blood contained in the auricles, exercises upon them, when these cavities are simultaneously contracted. The foramen must be at such time shut, and its obliteration much more exact, than that of the opening of the ventricles, by the mitral and tricuspid valves, or that of the aorta and the pulmonary artery, by the sigmoid valves. With all this, the foramen ovale is actually very often found open in the subject, and when not so, nothing is easier than to destroy the species of adhesion which is contracted by the two valves which close it. This may be done with the handle of a scalpel, without any solution of continuity, the parts appear to be unglued.

The oval hole when in this way artificially made, presents the same disposition, with that which is sometimes exemplified in the carcase. Now if this disposition be examined, it will be seen that when the auricles contract, the blood must make an obstacle to itself, and that it cannot pass from one into the other of these cavities. It is an easy thing to be convinced of the mechanism of which I speak, by means of two injections of a different colour, made at the same time from both sides of the heart, from the vena cava, and the pulmonary veins.

From what we have said of the influence, which is exercised by the movement and the different principles of the blood, it is evident that the death of the white organs must be different from that of the red ones. Asphyxia can hardly reach them, but of the manner in which they die I confess that I know but little.

CHAPTER IX.

OF THE INFLUENCE OF THE DEATH OF THE LUNGS, OVER THE GENERAL DEATH OF THE BODY.

In recapitulating what has been said in the preceding chapters. with respect to the influence of the lungs over the heart, the brain, and all the organs, it is an easy matter to form an idea of the successive termination of the whole of the functions, when the phenomena of respiration are suspended either mechanically or chemically.

The following is the manner in which death supervenes, when the mechanical phenomena of the lungs are interrupted, either from the causes mentioned in the 5th chapter, or from similar ones, such as the rupture of the diaphragm, which I have twice had occasion to observe,*

* When the diaphragm is ruptured, a sudden cessation of the functions is not always the result of this accident. Patients have been known to survive many days, and the cause of death has only been ascertained by examining the body.

The intercostal muscles are, in this case, the sole agents of respiration, which becomes nearly analogous to that of birds or to that of animals with red and cold blood, who are destitute of the septum between the thorax and abdomen.†

Lieutaud cites various ruptures of the diaphragm, produced by other causes than external injuries. Diemerbroech has seen this muscle wanting in an infant who still lived to the age of seven years.

† When from any cause, the diaphragm cannot contract, the enlargement of the thorax is effected solely by the elevation of the ribs, and as this motion is then very evident, we can then appreciate better the influence the intercostal muscles have in its production in ordinary respiration. Haller, as is well known, supposed that the first rib was almost immoveable, and that the muscles in the first intercostal space, took it as their fixed point to elevate the second. This second rib, in

or from a fracture of a great number of the ribs, or the sternum.

1st. The mechanical functions of the lungs cease. 2dly. The chemical functions of the lungs cease also. 3dly. The cerebral actions are put an end to. 4thly. The animal life is interrupted. 5thly. The general circulation is interrupted. 6thly. The capillary circulation is interrupted.

The phenomena of death, are differently concatenated, when they begin by the suspension of the chemical functions of the lungs: which may happen, 1st, From breathing in a vacuum: 2dly, From the obliteration of the passage of the trachea, by foreign substances introduced into it, or by tumour from without, or strangulation, accumulation of fluid in the air cells, &c.; 3dly, From different inflammatory affections, schirrhi, &c. of the cavities of the mouth or throat. 5thly. From want of respirable air, as on the summit of high mountains. 6thly,

its turn, served as a fixed point to elevate the third, and thus on to the last rib. But if we observe the mechanical phenomena of respiration when the diaphragm does not contract, as is the case in diaphragmatic pleurisy, we see that the first rib is far from being immoveable. Now, we cannot conceive how the intercostals which are attached to its inferior part, can, by contracting, assist in raising it. Besides, in order to elevate the ribs, a very great resistance must be overcome, and the intercostal muscles are too slender to induce us to suppose that they are capable of effecting it. The principal agents of this motion then are the anterior and posterior scaleni, which are distinctly seen to contract in great inspirations, the supra-costales and the muscles of the neck which attach it to the sternum. We ought to add to these a muscle, to which this use has never before been attributed; I mean the diaphragm. This muscle in fact in its contraction tends to become flat, from being concave as it is in inspiration. Now, its middle part in depressing the abdominal viscera experiences a certain resistance, and takes, as it were, from them a fixed point, by means of which it elevates the base of the thorax to which its circumference is attached.

From the introduction into the air cells, of non-respirable gases, &c. &c. In all these cases, the following is the order of the phenomena of death.

1st. The chemical functions of the lungs are suspended. 2dly. The functions of the brain are interrupted. 3dly. Sensation, locomotion, the voice, the mechanical phenomena of respiration cease. 4thly. The action of the heart, together with the general circulation is annihilated. 5thly. The capillary circulation is put an end to, together with the processes of secretion, exhalation, absorption, and digestion. 6thly. The animal heat of the system dies away.

I. *Remarks upon the differences of asphyxiæ.*

The influence of the black blood as I have said, is always the great agent in this double sort of death, but it is not the only one: if that were the case, the phenomena of all the asphyxiæ would be alike. It is true that in every sort of asphyxia, the black blood ceases to become red blood, and circulates in the arteries, such as it is in the veins; but notwithstanding the uniformity of this phenomenon, there can be nothing more varied, than the symptoms and progress of these accidents. In some of them, death is long in taking place; in others, almost instantaneous: the phenomena developed in the last moments of existence, are alike in none of them. The state of the organs, and that of the powers which they preserve after death, are as various.

1st, Asphyxia varies with respect to its duration; in sulphureted hydrogenous gas, in nitrous gas, and certain vapours arising from privies and sewers, it is quick in taking place. In carbonic acid gas, azot, in pure hydrogen, water, and a vacuum, its progress is slower.

2dly, Asphyxia varies with respect to its attendant phenomena. At times, the animal is violently agitated and suddenly convulsed; at others, it appears to lose its powers gradually; to pass into a state of sleep, and from sleep into a state of death. In comparing the numerous effects arising from the vapours of sewers, from those of charcoal, from the different gases, from drowning, and other causes of asphyxia, we find them almost as various, as the causes themselves.

3dly. The phenomena which make their appearance after death, are as variable. Compare the cold and frozen carcase of a drowned man, with the remains of one who has been suffocated. Read the result of the different experiments of the Institute, upon the affections of the galvanic fluid in the different asphyxiæ; examine Halle's detail of the symptoms which accompany the mephitism of sewers; approximate the numerous observations, which are scattered about in the works of Portal, Louis, Haller, Troja, Pechlin, Bartholin, and Morgagni; repeat the most common experiments on the submersion, strangulation, and suffocation of animals; and you will observe the greatest difference in all these sorts of asphyxia, they are each of them characterized, by a peculiar state of the bodies of the animals, which have been submitted to the experiment.

To inquire into the causes of such differences, we must first divide the asphyxiæ into two classes. 1st, Into those which happen from the simple want of respirable air, and 2dly, Into those, where to this first cause is joined also that of the introduction of some deleterious substance into the lungs.

In the first class, the immediate cause of death, appears to be the simple presence of the black blood, in the various parts of the body, the general effect of which is always the same, in whatever manner produced; accordingly, the attendant symptoms and secondary results of all these sorts of death, are nearly alike, their duration the same, and if it varies, it varies only in consequence of the more or less complete interruption of the passage of air into the lungs.

This variety in the duration and intensity of the asphyxiating cause, may nevertheless occasion some variety in the symptoms also; such as a greater or less lividity and swelling of the face, a more or less considerable embarrassment of the lungs; but all these differences indicate only so many modifications of the cause. 1st, A man who is hanged, does not die as a man who is suffocated by an inflammatory tumour, or a pea or bean which perchance may have fallen into the trachea.* 2dly, An animal will perish much more slowly under a vessel of air, than when the trachea is tied. 3dly, The symptoms of asphyxia, when occasioned by a great rarefaction of air, or by a suffocating heat, are much less slowly produced, than where the cavity of the lungs is opened.

In all these cases the cause of death, namely the absence of red blood in the arterial system, is simple and unique, but according to the greater or less oxygenation of the venous blood, will be the appearances after death, for the longer the process of asphyxia endures, the less irritability will there be found in the system.

But if the cause of asphyxia, have been the introduction of some deleterious fluid into the lungs, then the

* Asphyxia is not always the cause of death in those who are hung, there is sometimes connected with it a more efficient cause, which consists in the compression of the spinal marrow. This was formerly very often observed in those who had been executed, because the executioner in throwing them off gave a rotatory motion to the body which produced the luxation of the first vertebra on the second.

variety of the symptoms will depend upon the difference in the nature of the fluid. In these cases the cause is of two kinds: 1st, There is no red blood in the system. 2dly, A pernicious fluid is present in the system. All the gases however do not act as deleterious substances: in pure hydrogen for instance, the animal perishes only as it would from the want of respirable air.

But when a man in descending into a common sewer, into a cellar, or into any place where putrid matters are accumulated, falls into asphyxia at the moment when he inspires their exhalations, and when such state is attended with convulsive movements and extreme agitation, then indeed, there must be something more in the cause of his death, than a simple suspension of the chemical functions of the lungs.

In fact, together with the mephitic vapour, there continues to enter into the lungs a sufficient quantity of air to keep up life and its different functions. 2dly, Supposing even that the quantity of mephitic air were such as to leave no place for the entrance of respirable air, still the death ensuing should only be gradual, without agitation and convulsion, were it occasioned only by the absence of such air: now the very different way in which it supervenes, very evidently indicates the action of a deleterious substance, upon the animal œconomy.*

* By injecting into the veins different irrespirable gases, Nysten has been able to distinguish the effects which result from the deleterious properties of the gases from those which arise from the alteration of respiration from a want of atmospheric air.

Thus among the elastic fluids which he tried, he found sulphuretted hydrogen, the deutoxide of azote, chlorine and ammoniacal gas eminently deleterious; for introduced in sufficient quantity into the animal economy they uniformly cause death, whilst others, such as oxygen, azote, hydrogen, carburetted hydrogen, carbonic acid, oxide of carbon, and protoxide of azote do not produce death when introduced into the

These two causes then act together, in those asphyxiæ which are produced by certain gases, sometimes the one predominates, sometimes the other. If the deleterious substance be violent, it kills before the action of the black blood can have produced much effect, if weak, it is the black blood, which is principally the cause of death.

The asphyxiæ then, which are produced by the gases, differ only, in consequence of the nature of the deleterious substance, which varies adinfinitum. In some of the aeriform fluids indeed it is supposed to be known, but in the greater number of them it is not so:* I shall notice therefore in a general way the effects, which result from the action of the deleterious substance, remarking at the

lungs, except by excluding the only mixture, that can support respiration; in no other way do they occasion death, at least in a sudden manner. If however, they are thrown quickly into the blood vessels, they cause death, but it is mechanically and in the same way as atmospheric air would do it. It should also be observed that these different gases do not all act in the same way when they are introduced into the lungs; the gaseous oxide of carbon destroys animals much quicker than azote or the protoxide of azote. They die also quicker in the prot-phosphuretted hydrogen, and even in the carbonic acid gas. There are also in the action of deleterious gases certain anomalies which have not hitherto been explained. Nysten injected, at three injections, into the veins of a dog of middle size thirty centimetres of sulphuretted hydrogen. The animal after the first injection, was agitated, and made powerful inspirations; the second produced convulsive motions and the third apparent death; but the next day he was entirely well. Now a less quantity of sulphuretted hydrogen carried into the organs of respiration and mixed with five or six hundred times its volume of air, would infallibly destroy the animal.

* The composition of some of these vapours is better known at the present day; but there are others in which our means of analysis have been unable to detect the deleterious principle; thus in the *malaria*, which has depopulated the country in the neighbourhood of Rome, our chemists have as yet only found as constant elements, those which enter into the composition of atmospheric air.

same time, that the symptoms by which they are displayed, are strongly or weakly marked, according to the age and temperament of the individual.

Deleterious substances introduced into the lungs, together with the mephitic vapours of which they form a part, can act only in two ways. 1st, By affecting the nerves of the lungs, which re-act on the brain. 2dly, By passing into the blood, and exercising their influence, by means of the circulation on the various organs of the system.

I can easily believe that the simple action of such a substance on the nerves of the lungs, may have a very marked effect on the economy, and be capable of troubling the functions of the system very sensibly ; much indeed in the same way as with some individuals a mere odour, or the sight of a hideous object, will occasion syncope, in the same way that an irritating enema will suddenly awake the system into life, or the introduction of certain substances within the stomach, will be felt throughout the body, before such substances can have passed into the circulatory torrent. We meet at every moment with examples of these very remarkable phenomena, produced by the simple impressions of foreign bodies on the mucous surfaces ; I cannot deny that deleterious substances may act in the same way upon the nerves of the lungs, though we must not exaggerate the sphere of this mode of action.*

In fact, I am not acquainted with any one example, where the contact of a deleterious substance with a mucous membrane, has been the sudden cause of death. It may indeed be productive of such effect after a certain time, but never at the moment of its action ; nevertheless, in those asphyxiæ which are produced by mephitic

* It appears from the experiments of M. Desormes that the contact of sulphuretted hydrogen on the skin of an animal is immediately fatal.

vapour, so rapidly does death come on, that the black blood can scarcely have had the time to exert its influence upon the body. The principal cause of the cessation of the functions is manifestly the action of the pernicious substance.

These considerations, then, incline me to believe, that these substances pass into the blood through the lungs, and that in circulating with the blood they carry to the organs the immediate cause of their death. Such passage into the blood has already been suspected by many physicians; the truth of the fact appears to be indubitably proved by the following reflections.

1st, It can hardly be doubted, that the poison of the viper and many other venomous animals, and that the saliva of rabid animals, pass into the system of the blood, and are taken up either by the veins or the lymphatics.

2dly, It appears to be very certain, that a portion of the atmospheric air is actually absorbed through the mucous membrane of the lungs itself, and not by means of the absorbent system. Now, if this be the case, I know not what should hinder the passage of mephitic vapour in the same way.* We are not sufficiently acquainted with the limits of the particular sensibility of the membrane of the air cells, to say that it cannot give a passage to such vapour.

3dly, The respiration of an air which has been charged with the exhalations arising from oil of turpentine, com-

* We know that fine injections pass from the branches of the pulmonary artery into the divisions of the bronchia; and that even water, when pushed into the trachea, will return, at least a small quantity of it, by the pulmonary veins and arteries.

Bichat thought that the gases absorbed in the lungs must pass through the mucous membrane; but this is not the case unless absorption takes place at the time they are in the bronchia, for the mucous membrane which lines the air-tubes does not extend into each bronchial lobule.

municate a particular smell to the urine. It is thus that this fluid is affected from the residence of the persons in a newly varnished room. In this case it is evidently by the lungs in part, that the odoriferous fluid has its passage into the blood, and so on to the kidneys. In fact, I have often assured myself by breathing out of a bottle through a tube, air so charged (in which case it could not act on the cutaneous surface) that the smell of the urine undergoes a change. If, then, the lungs will admit a variety of substances, which do not enter into the composition of respirable air, for what reason should they not admit the mephitic vapour of mines and subterraneous places.

4thly, The respiration of humid air produces dropsy. The extent of the fact has been exaggerated, indeed, but the fact itself is true. It proves, that an aqueous fluid may pass into the blood, and consequently that other substances may pass into it also.

5thly, If an animal be asphyxiated in sulphurated hydrogenous gas, and a plate of metal some time after its death be placed under one of its muscles, the surface of the plate contiguous to the muscle, will be sensibly sulphurated. The foreign principle, then, which is here united with the hydrogen, must have been introduced into the circulatory torrent by the lungs, and have penetrated with the blood into all the parts. The deputies of the Institute have observed this phenomenon in their experiments. I have made a similar remark in asphyxiating animals with nitrous gas. A phenomenon of the same nature accompanies the exhibition of mercury.

From the above, we have nearly a right to conclude, that the different deleterious substances of which the gases are the vehicles, do actually pass into the blood, and so affect the organs. Of this matter, however, I shall adduce some further proofs.

I have ascertained by a number of experiments, that atmospheric air, or any other aeriform fluid, may be made to pass into the blood without alteration.

Divide the trachea of a dog, inject the air-cells strongly with common air, and continue to retain it in the lungs. The animal will immediately discover signs of great distress and agitation ; if an artery now be opened, the blood will be emitted in a frothy state.

If hydrogen have been employed, it may easily be ascertained that the nature of the fluid is unchanged, by placing a candle over the bubbles which are disengaged.

When the blood for the space of thirty seconds has flowed in this state, the animal life of the creature will be finished, and death ensue, with all the symptoms which accompany the insufflation of air into the black-blooded system of vessels. The re-admission of air into the lungs, will have no effect in restoring the animal to life, for as soon as frothy blood can flow from any one of the arteries, it must already have affected the brain with its pernicious influence.

In this case it may be perceived, that the causes of death are the same as those which proceed from the insufflation of air into a vein. In the one instance the air passes at once from the lungs into the arterial system. In the other, from the veins across the lungs and then into the arteries.

When we open the bodies of animals, which have been killed in these experiments, the whole apparatus of the red-blooded vascular system, is found to be filled with air bubbles of various sizes. In some circumstances, the blood will be transmitted in the same state into the general capillary system, and from thence into the veins ; in others it will be stopped in the capillary system, and in such cases, though the circulation may have continued for some time after the suspension of the animal life, not a single particle of air will be discovered in the veins.

In these experiments which I have frequently repeated, I have never found that the least fissure has been made in the bronchiæ; nevertheless, I confess that it is difficult to say, whether this be so in their last ramifications. The following phenomenon, however, may throw some light upon the subject; for as often as air is pushed into the lungs with great violence, there will be produced an emphysema of the breast, or neck, from the infiltration of this fluid among the cellular texture, in addition to its passage into the blood. But if the impulse be moderate, and the quantity of air injected not much beyond the measure of a full inspiration, it will pass into the blood only, and not into the cellular texture.*

* This fact, frequently confirmed in my experiments, is not always the same in man. We often see emphysema produced by violent efforts of respiration, efforts which have forced into the cellular organ the air contained in the lungs. Now, if the passage of the air in the blood preceded or even accompanied its introduction into the neighbouring cells of the bronchia, all these cases of emphysema would be necessarily fatal, and even in a sudden manner, since, from what has been said before, the contact of the air on the brain, to which the circulation would carry it, would inevitably interrupt the functions of this organ.

Yet we see that emphysema is often cured, or does not produce death for a length of time.† I saw, at the Hotel-Dieu, an air tumour, suddenly

† I saw, in a little girl of seven or eight years of age, an emphysema which occurred in a paroxysm of coughing, and which extended to the thorax, the abdomen and the superior part of the thighs; the swelling of the neck was so considerable, that at the moment I was called suffocation was imminent. I made, in the skin above the sternum, an opening, which very quickly produced an evacuation of the air. In five or six days, though the hooping cough continued, this little patient was entirely cured of the emphysema, which had been very near destroying her. It did not appear to me that the lungs had participated at all in the general emphysema.

The experiments of which I have given the detail, exemplify phenomena which do not indeed take place in the

appear in the axilla, from the violent efforts of the patient to prevent respiration, whilst Desault reduced an old luxation. In a few days this tumour disappeared without producing any inconvenience. We find, in the Memoirs of the Academy of Surgery and in Treatises on Operations, various examples of emphysema produced by powerful agitations of the thorax, and in consequence of the introduction of a foreign body into the wind-pipe; emphysema, with which the patients have lived many days, and from which even they have recovered.

There is then no doubt, that often in man the air passes from the lungs into the cellular texture, without entering the arterial system. My experiments on animals have not been exactly analogous to what happens from the introduction of a foreign body, when a part of the air enters and goes out. It is then probable that from a cause precisely similar would arise also the same effect in animals.

And vice versa, the passage of the air in the blood-vessels sometimes takes place in man, without the infiltration of the cellular organ; then the death is sudden.

A fisherman, subject to colick, was suddenly seized with it in his boat; the abdomen swelled, the respiration became painful and the patient died almost instantaneously. Morgagni opened the body the next day, and found the vessels full of air. Pechlin also says he saw a man die suddenly in great distress and with a hurried respiration, and he afterwards found a large quantity of air in the heart and in the large vessels.

I have dissected many bodies, in which, before death there had been a sanguineous congestion in the exterior capillary system of the face, the neck and even of the thorax. This system exhibited a remarkable engorgement and lividity in all its parts, and I have found in opening the arteries and veins, in those of the neck and head especially, a frothy blood mixed with bubbles of air. I learnt that one of these subjects died suddenly with a convulsive affection of the pectoral muscles; I have no information respecting the others. Besides, all who have had much to do with dissecting rooms, must have seen bodies of this kind, which very soon become putrid and emit an insupportable odour. They have observed also that the air in the vessels existed previous to the putrefaction.

I suspect that in all these cases death has been produced by the sudden passage of air from the lungs into the blood, which has after-ordinary process of inspiration, and therefore I allow that no very rigorous induction can be drawn from them, with respect to the passage of deleterious substances into the mass of the blood; nevertheless it appears to me, that they very much confirm the probability of such fact, which besides is demonstrated by many of the preceding remarks. I shall conclude, then, that such passage is real. In fact, we have seen 1st, That the sole transmission of the black blood into the arteries, will not account for the infinitely various phenomena exemplified in the different sorts of asphyxiæ; 2dly, That the simple contact of the deleterious substance with the nerves of the lungs, can by no means be the cause of a death so rapid as that which is occasioned by these accidents; 3dly, That, therefore, we are forced as it were to suspect the passage of the poison itself into the blood; 4thly, That a number of considerations are in favour of such suspicion, and thus that the fact is proved both directly and indirectly.*

This principle being once established, a variety of results must flow from it. Of the first of these, of the mode of action, namely, which the deleterious substance

wards carried it to the brain; nearly like what I have said takes place, when, in a living animal, we force much air towards the lungs, and thus drive this fluid into the vascular system.

By considering these phenomena in connexion with the remarks presented above on death from the injection of air into the veins, the opinion I have advanced, will I think, be admitted, and it is besides the opinion of many other physicians. Many experiments have already been made on the dead body relative to this point. Morgagni has presented them in detail; but it is on the living that we must observe the passage of the air into the blood in order to deduce consequences which shall bear on the subject on which we are treating. We know in fact what is the influence of death on the permeability of the parts.

* The above experiments explain the manner in which emphysema is produced from any very violent exertion of the muscles of the chest.

must exercise upon the different organs, I shall say nothing, having nothing to offer but conjecture.

I shall accordingly content myself with inquiring what system it is which is particularly influenced by these substances, when mingled with the blood.—Now, 1st, This system appears to be the nervous one, and that portion of it especially, which presides over the parts of the animal life, the organic functions being only secondarily affected ; 2dly, Of all the nervous system, the brain is that part which is the most affected ; 3dly, Under this relation Monsieur Pinel appears to me to have been right, in placing some of the asphyxiæ (those for instance which are occasioned by the presence of a deleterious substance) among the neuroses. On this head the following considerations should leave us little doubt.

1st, In all the asphyxiæ, when the presence of a deleterious substance cannot be doubted, the symptoms consist of two general and opposite sets of phenomena, of spasm and torpor. Of two workmen who had come up out of the sewer of the street St. André dés Ares, the one sat himself down upon a bulk, and fell into a state of asphyxia; the other with irregular convulsive movements, proceeded as far as the rue Battoir, and then fell down asphyxiated. The Sieur Verville, in consequence of inhaling the breath of a man who was lying in a state of asphyxia from the vapour of lead, fell down suddènly, and in a short time became convulsed. The vapour of charcoal intoxicates, as it is said. I have seen animals asphyxiated with other gases, and perishing with a stiffness, such as could be produced only by the most violent spasm. The centre of all these symptoms, and the organ from which they emanate, undoubtedly is the brain, and they depend upon its irritation or compression.

2dly, The animal life is always interrupted before the organic life, wherever the asphyxiating cause has been of a compound nature. Now the centre of the animal life is the brain.

3dly, I have proved when the animal perishes from the circulation of the black blood in the arteries, that the brain is especially affected even then; but in the same way, that is, by the cephalic arteries, the deleterious substance itself, may be introduced into the brain.

4thly, I have pushed a variety of deleterious gases (for example, sulphurated hydrogen) into the brain, and also some of those substances which vitiate the nature of these gases. The animal has always perished with symptoms of spasm, or torpor, and in general the death which is occasioned by the different gases, is always similar to that which is produced by the introduction of pernicious substances into the brain.

5thly, The consequences of these asphyxiæ, when life has been restored, invariably suppose a lesion of the cerebral system, such consequences consist of palsy, tremour, wandering pains, and derangements of the exterior apparatus of the senses.

From all these multiform experiments and considerations, we may surely conclude, that it is on the brain and nervous system that the deleterious principle, introduced into the blood, must act; from the death of these parts, that of the others is derived.

In this case the different organs no doubt are directly enfeebled, and may perhaps be immediately affected by those principles, which flow into them together with the blood, but all such phenomena, are even more visible in the animal, than in the organic life.

Let us not forget however, that a part at least of the cause of this sort of death, consists in the influence of the venous blood upon the organs, and that this influence must ever be in proportion to the length of time that such blood continues to circulate. The differences then which are found in the asphyxiæ, may be said to proceed from the greater or less effect of the venous blood upon the system, from the different nature of the various deleterious substances inspired, and from the age and temperament of the individual affected.

II. *In the greater number of diseases, death commences in the lungs.*

I have just spoken of sudden death. I shall now enlarge a little on that which is the slow effect of disease. Physicians must be well persuaded, that by far the greater number of diseases, put an end to life by an affection of the lungs. Whatever be the seat of the principal affection, be it either an organic lesion, or a general disorder of the system, the action of the lungs in the latter moments of existence, becomes embarrassed, the respiration difficult, and the oxydation of the blood, but slowly effected; accordingly this fluid must pass into the arteries, almost in the venous state.

The organs therefore which are already enfeebled, must be much more readily affected by the pernicious influence of such blood, than those which are subject to it, in the different cases of asphyxia. In this way the loss of sensation, and intellect, are very shortly the effect of embarrassment in the lungs; and ensue as soon as the brain begins to be penetrated with the fluid which is so transmitted to it.

By degrees the heart and all the organs of the internal life, cease also to move. It is here the black blood which arrests these vital motions, which have already been enfeebled by the disease. Such weakness, the consequences of the disease, is very rarely the immediate cause of death, it only prepares it, by rendering the organs more susceptible of the alteration in the healthy state of the blood. Such alteration is almost always the immediate cause of death. The disease then, is only an indirect cause of death in general, it kills the lungs, and the death of the lungs occasions that of all the other parts.

From hence it may be easily conceived, why the small quantity of blood contained in the arterial system of the subject, is almost always black. For 1st, The greater number of deaths begin by the lungs. 2dly, We shall see that those which have their commencement in the brain, are equally the cause of this phenomenon. Accordingly there can be only those, in which the heart ceases suddenly to act, after which the red blood can be found in the aortic ventricle, and auricle. Such appearance is seldom found, excepting in the bodies of persons who have perished from extensive hemorhagy.

From the frequency of deaths beginning with an embarrassment of the lungs, may be conceived also the reason, why this organ is so frequently gorged with blood in the carcase in general, the longer the agony, the heavier and fuller are the lungs. When such fulness is found, together with black blood in the red-blooded system, whatever the disease may have been, it may be pronounced that death has begun in the lungs. In fact the concatenation of the phenomena of death is from one of the three organs, from the lungs, brain, or heart, to all the others. Now when death begins in the heart, the pulmonary vessels are generally empty, and there is red blood in the aortic system. On the other hand, if death have began in the brain, there is then indeed a certain quantity of blood in the arteries, but the lungs are empty, unless, when gorged with blood, by some antecedent affection.

CHAPTER X. 305

OF THE INFLUENCE OF THE DEATH OF THE BRAIN OVER THAT OF THE LUNGS.

As soon as the human brain ceases to act, the functions of the lungs are suddenly interrupted; this phenomenon, which is constantly observed in the red and warm-blooded animals, can happen only in two ways. 1st, Because the action of the brain, is directly necessary to that of the lungs, or 2dly, Because the latter receives from the former, an indirect influence by means of the intercostal muscles and diaphragm, an influence, which ceases with the activity of the cerebral mass. Let us try to determine which of these two modes is that of nature.

I. *Is it directly that the lungs cease to act upon the death of the brain?*

I shall have proved that the death of the brain, is not immediately the occasion of that of the lungs, if I can determine that there is no immediate influence exercised by the first, upon the second of these organs, now, this essential principle may be easily demonstrated by experiment.

The brain can exercise an immediate influence on the lungs, only by means of the par vagum or the great sympathetic nerve, the only nerves, which according to the common opinion, establish a communication between the two organs (an opinion however which is erroneous, as the great sympathetic is only an agent of communication between the organs and the ganglions of the system.) Now 1st, The influence which is derived by the lungs from the par vagum, is not actually necessary for them to act. The following experiments will show the truth of this assertion.

1st, Irritate the par vagum on one or both sides, and the respiration of the animal will be somewhat quickened; but such appearance is no proof of an immediate influence, for any wound of the neck, or any wound whatever, provided that it be the occasion of considerable pain, will be the cause of a similar phenomenon.

2dly, Cut one of the nerves, and the respiration will be at once affected, as when the nerve is irritated; but as soon as the pain ceases, the embarrassment of the lungs will disappear; and at the end of four and twenty hours, the phenomena of life be concatenated with their accustomed regularity.

3dly, Divide these nerves on both sides. In this case the breathing will be much more precipitated, and will not return to its ordinary state, as in the preceding experiment; it continues laborious for four or five days, and the animal perishes.*

* The division of the nerves of the eighth pair in the neck produces two kinds of effects, which should be carefully distinguished; the one relates to the larynx and the other to the lungs. Among the first, aphonia is one of the most striking symptoms. We see a very good reason for this phenomenon, when we recollect that the recurrent nerve is a branch of the eighth pair; but besides the loss of voice, the division of the eighth pair often produces such an approximation of the edges of the glottis that the air cannot enter, and death immediately takes place.

Most usually, the approximation is not sufficient to prevent entirely the entrance of the air into the thorax; but as the glottis has lost its

From the two latter experiments it follows, that the par vagum is indeed necessary to the phenomena of respiration, and that the brain must exercise, of course, an influence over this function, but at the same time, it may be seen, that without the immediate influence of the motions in relation with those of respiration, this function is always performed in a more or less incomplete manner.

When these observations were first made, it was hardly possible to give an accurate explanation of them; but since I have ascertained the manner in which the recurrent and laryngeal nerves are distributed to the muscles of the larynx, there is no longer any difficulty. By the division of the eighth pair at the inferior part of the neck, the dilator muscles of the glottis are paralyzed; this opening does not enlarge at the moment of inspiration, whilst the constrictors, which receive their nerves from the superior laryngeal, preserve their action entire, and shut more or less completely the glottis.

When the division of the eighth pair does not close the glottis so completely as to produce death immediately, another order of phenomena is developed.

The respiration is at first embarrassed, and its rhythm often experiences a remarkable alteration; the inspiration is slow, and the expiration quick and short. The animal is averse to motion and seems to be easily fatigued. At first the formation of the arterial blood is not prevented, but soon its vermilion colour changes, it becomes darker and approximates more and more that of the venous blood. The temperature falls, and the very embarrassed respiration is only made by the aid of all the muscular powers; the coldness becomes evident, and the animal soon dies.

As this series of circumstances is developing, the animals, on whom the experiments are made, consume less oxygen, and form less carbonic acid.

We find, on opening the body, the bronchia filled with a frothy, and sometimes a bloody fluid; the lungs are engorged, and the divisions of the pulmonary artery are much distended with very black blood.

From all that has now been stated, it is natural to conclude that, in this last case, the animals die because respiration can no longer be effected, the lungs being so altered that the air cannot get into the bronchial cells. To this cause should be added also the difficulty which the blood experiences in passing from the arteries to the pulmonary veins.

brain, the lungs will continue in play, and consequently that the interruption of such influence, as when the brain is injured, will not be an immediate obstacle to the continuation of the pulmonary actions.

The question whether the functions of the lungs are more immediately connected with the influence derived from the ganglions, may be decided by the following facts.

1st, If on the one and the other side of the neck, the nervous thread be cut, which is usually regarded as the trunk of the great sympathetic, there follows little or no alteration in the phenomena of respiration.

2dly, If the par vagum and the great sympathetic be divided at the same time on both sides of the neck, the animal will die after a certain time, and much in the same way, as when only the par vagum is divided.

3dly, When we divide the sympathetic nerve in the neck, we do not deprive the lungs of the nerves which come from the first thoracic ganglion; now these nerves may contribute to keep up the action of the lungs, since, as I have said, each ganglion is a nervous centre, capable of emitting its own peculiar irradiations, independently of the other centres, with which it communicates.

But whether the nerves, which are derived from the first thoracic ganglion, do really assist the functions of the lungs, I have not been able to ascertain by experiments on the nerves themselves, for such is the position of the first thoracic ganglion in most animals, that it cannot be taken away without doing so much injury to the parts as would kill the creature, or throw it into such agitation, as wholly to confound the phenomena of which we are in search, with those of a general distress and trouble. From analogy, however, and from the destruction of other ganglions, by which the internal organs are supplied, we should not have a right to suppose that the lungs would cease to act, when the ganglion in question is destroyed.

Besides, the following reasons appear to me to prove unquestionably, the principle which I advance. If great lesions of the brain have the effect of suddenly interrupting respiration, because this organ can no longer influence the lungs by means of the nerves, which come from the first thoracic ganglion, it is evident that if all communication between the brain and this ganglion be taken away, such influence must cease, and respiration be suspended; but if we divide, as Cruikshanks has done, the spinal marrow on a level with the last of the cervical vertebræ, the animal will continue to live and breathe for a length of time, notwithstanding the want of communication between the brain and the lungs, by means of the first thoracic ganglion. From the above experiments, we may conclude, that the brain does not exercise any direct and actual influence over the lungs, and consequently that other causes must be sought for, if we mean to account for that sudden and instantaneous cessation of the functions of the latter of these organs, when those of the former are suspended.

There exists, notwithstanding, a phenomenon which seems to cast some doubt upon the conclusion which I have deduced, and in the principle which it establishes. I speak of the sudden difficulty of respiration, and that impeded circulation which are occasioned by violent pain. This distress appears to indicate that the heart and the lungs are dependent immediately upon the brain; for the distress is in the brain, say the greater number of authors, and the affection of the heart and lungs, a consequence of the reaction of the brain; but here let it be remembered, that almost all pain is made up, first of sensation, and secondly of some *emotion, passion* or *affection.** Now as I have proved at length, in the former part of this work, all passion and emotion have their seat in the internal viscera, and thus it will appear, that the trouble which in such case is felt in the heart and lungs, does not depend upon the brain for its cause, but is the immediate effect of the passion, or emotion, which accompanies the sensation. The following considerations will bear me out in this conclusion.

1st, In many instances the dyspnœa and impeded circulation, precede the pain. Examine the thorax, and place your hand upon the heart of a man about to undergo an operation, and you will be easily convinced of this truth.

2dly, There is sometimes a manifest disproportion between the sensation of pain, and the distress which is experienced about the heart, and in breathing. I have known the operation of cutting away the prepuce immediately fatal. Now in this case, it surely could not be pain which killed the man.

3dly, There are many persons who are capable of supporting violent pain, with resolution. Place your hand upon the heart of such persons, and no agitation whatever will be felt there. Nevertheless, their perception of pain must be what it is in other persons.

4thly, In the course of an operation, we are not to judge of the patient's state of mind, from his cries, or silence. This sign is very deceitful; because a man may be sufficiently master of himself to overpower the influ-

* These words *passion*, *emotion*, *affection*, &c. have, I know, real differences in the language of metaphysicians; but as the general effect of the sensations which they express is always the same on the organic life; as this general effect is what alone concerns me, and as the secondary phenomena are of no importance, I use these words indifferently for each other.

ence of his internal organs. We must examine the heart and lungs; their functions, if I may allow myself the expression, are the thermometer of the affections of the mind. It is not without reason, that the actor who plays the part of a courageous man, takes hold upon the hand of him whom he wishes to set at ease, and lays it on his heart. The exterior movements of the passions, are not a fair criterion of the inward feelings of the individual, for these movements may be feigned as well as real: feigned if they originate in the brain: real if they have their sources in the heart;—in the first case voluntary, in the second involuntary. Touch the pulse of the angry man, if you wish to know whether he really is in anger. When I see a woman weeping or convulsed at any distressing news, and find her pulse in its natural state, I know what to judge of her affliction.—On the contrary, if her grief be concentrated, but her heart beat strongly, or her pulse have been suddenly depressed, I know that she feigns a calm which she does not feel. To judge correctly, we must always compare the external movement with the state of the internal organs. There could be no deceit, were it possible to distinguish the involuntary movements produced in a state of passion, by the action of the heart upon the brain, and then by the reaction of the brain upon the muscles, from the voluntary movements which are occasioned by the simple action of the brain upon the locomotive system.

However strong may be the pain which has been the occasion of the dyspnœa, and impeded circulation, of which we have been speaking, this dyspnoea and distress about the precordia, will cease, provided only that the pain be continued. Nevertheless, if the reaction of the brain were the real cause of the distress in question, the contrary should be the case; for the continuation of the affection of the brain, should continue also to cause its re-action. But here the effect of habit is evident, though the pain subsists; the brain indeed continues to be affected, but the internal organs cease to be so. It may be easily perceived, that I am not here speaking of those cases, where the action of the heart and lungs has been deeply troubled by the effect of pain.

To the above considerations I might add many others, with the view of proving, 1st, That although the brain be the seat of the pain, it is not the source of those affections of the internal organs, which are occasioned by such pain; 2dly, That these affections depend upon an emotion, which is absolutely distinct from sensation of whatever kind, both in its nature and effects.

II. *Is it indirectly that the lungs cease to act upon the death of the brain.*

Since the death of the lungs, upon the cessation of the cerebral action, is not direct, there must exist between the brain and the lungs, some intermediate agents, the cessation of whose functions, occasion the cessation of those of the lungs. These agents are the diaphragm, and intercostal muscles; for they depend immediately upon the brain by means of the nerves, which they receive from it, and consequently become paralytic on the death of the brain; the following experiments are a proof of the fact.*

* We have said in a preceding note, that the division of the nerves of the eighth pair could produce death in two ways; first, by closing the glottis, and preventing the entrance of the air into the air tubes; secondly, by altering the lungs and preventing the production of the chemical phenomena. Of these two kinds of death the first is in some measure accidental; it is an indirect effect of the interruption of the action of the brain; but it is not so with the second, and though it may not be instantaneous, it is not less a direct effect of the division. It

1st, Cruikshanks divided the spinal marrow of a dog between the last cervical, and the first dorsal vertebræ. The intercostal muscles accordingly were immediately paralyzed, and the breathing of the animal continued to be made by the diaphragm only, which receives the phrenic nerve from a point above the section. In this experiment, it is easy to judge of the strong action of the diaphragm, by that of the abdominal muscles.

2dly, If the phrenic nerves only be divided, the diaphragm becomes immoveable, and then the respiration of the animal is effected by the intercostal muscles only.

3dly, After the two preceding experiments, the animal will live for a considerable time, but if the phrenic nerves, and the spinal marrow, towards the end of the neck, be divided at the same time, or what comes to the same thing, if the spinal marrow be cut above the origin of the phrenic nerves, then all communication between the brain and the active agents of respiration is cut off, and death follows of course.

4thly, I have frequently observed, that half an inch of difference in the place where the spinal marrow is divided, produces such a difference in its consequences, that in the one case the death is sudden, and supervenes in the other only, after an interval of fifteen or twenty hours. In dissecting the carcases of animals killed in this manner,

might be supposed that the motions of the glottis being destroyed, and the entrance of the air being rendered consequently more difficult, that it is in consequence of this obstruction that respiration is embarrassed, and that the alteration of the lungs is only a consecutive phenomenon. But in the experiments made by M. Dupuy at Alfort, a free passage was given to the air, by an opening made in the trachea. Now it cannot be believed that the small wound necessary for this opening, could contribute to produce the disturbance of the respiration, for a similar operation, is daily performed on horses, without producing the slightest inconvenience.

I have constantly observed that the difference depended always upon the circumstance, of the phrenic nerve being cut or not.

From these experiments then it is evident, that respiration ceases on a sudden, and in the following manner, in all lesions of that part of the nervous system, which is placed above the origin of the phrenic nerves. 1st, There is an interruption of action in the voluntary nerves, which are placed below the point of lesion, and consequently in the phrenic and intercostal nerves. 2dly, A paralysis of almost all the muscles of the animal life, and particularly of the diaphragm and intercostal muscles. 3dly, A cessation of the mechanical phenomena of respiration. 4thly, A suspension of the chemical phenomena of respiration. The interruption of all these movements, is as rapid as their concatenation is prompt, in the natural order.

It is thus that those persons perish, who experience any great lesion of the spinal marrow, between the brain and the origin of the phrenic nerves. Physicians have been very much embarrassed, in fixing with precision the spot, when a wound of the medulla ceases to be mortal; from what I have advanced, the limit is easily assigned.* From the same causes, concussion, and compression of the brain, are also fatal.

We should observe notwithstanding, that these different causes of death, may act with various degrees of intensity. If they act but feebly, they affect the intellectual functions only, for these functions are always the first to be altered, in all lesions of the brain however small. If the lesion be greater, the affection extends to the muscles of the limbs, and convulsion or palsy ensue. Lastly, if the

* The experiments of Legallois have clearly proved, that this point is at the origin of the nerves of the eighth pair.

lesion be very great, the whole of the muscles of the animal life, the intercostals and diaphragm, as well as the others, are paralyzed, and death follows.

We now can reply to the question proposed at the beginning of this section, and affirm that the death of the lungs is occasioned indirectly, by the death of the brain.

It follows also, from the principles which are above established, that respiration is a mixed function, a function placed as it were between the two lives, to which it serves as a point of contact, belonging to the animal life by its mechanical functions, and to the organic life, by its chemical functions; and hence we have the reason no doubt, why the existence of the lungs is as much connected with that of the brain, as with that of the heart.

It may be observed in the series of animals, that in proportion as the organization of the brain is straitened, a number of the phenomena of respiration also are lost. In birds, and the mammalia, this function as well as the brain, is much more developed than it is in the classes of fish and reptiles. It is known, that the nervous system of those animals which breathe by tracheæ, is less perfect than in those which breathe by lungs; and that in those, where there is no nervous system, that of respiration disappears also.

In general, there is a reciprocal relation between the brain and the lungs, especially in birds and the mammalia. The first of these occasions the action of the second, by raising the ribs and favouring the entrance of air into the bronchiæ; the second also keeps up the activity of the first, by means of the red blood which it sends thither.

It would be an interesting speculation to inquire into the relation of the nervous system with that of respiration in the class of insects, for as they receive the air by points, which open externally, there seems to be no mechanical action in the process of their breathing, and thus the function appears with them to belong entirely to the organic life.

CHAPTER XI.

OF THE INFLUENCE OF THE DEATH OF THE BRAIN OVER THAT OF THE HEART.

In the preceding chapter we have shewn how the lungs remain inactive, when the brain ceases to act.—The same phenomenon, under the same circumstances, takes place also in the heart, and must happen either immediately or mediately.

I. *Does the Heart cease to act immediately in consequence of the interruption of the cerebral action?*

The greater number of medical men, speak in much too vague a manner of the cerebral influence. They do not sufficiently determine its extent and limits, with respect to the different organs of the system.

It is evident that we shall have answered the question proposed at the head of this section, if we can determine what the influence of the brain is with regard to the heart. Now, we have every reason to suppose, that no direct influence is exercised by the former over the latter of these organs, which, on the contrary, is immediately dependent with regard to its operations, on the movement communicated to it by the blood. This assertion is by no means a new one. It has been admitted by all sound physiologists; but as many opinions in medicine are founded upon a contrary principle, it will not be amiss to dwell upon it a little. It is equally demonstrated both by observation and experiment—and to begin with the former:

1st, All violent irritation made upon the brain, produces either partial, or general convulsion in the muscles of the animal life. Examine those of the organic life, on the contrary, and little will be found amiss in their actions.

2dly, All compression of the cerebral mass, whether made by pus, water or blood, has ordinarily the effect of paralyzing the voluntary muscles; but so long as the affection does not extend to the muscles of the breast, the action of the heart is in no degree diminished.

3dly, Opium and wine, when taken in a certain quantity, diminish the cerebral energy for the moment and render the brain unfit for the functions of the animal life. The action of the heart, on the contrary, is increased.

4thly, In palpitation, and the different irregular movements of the heart, it is not observable that the principle of these derangements exists in the brain.—In this respect, as well as on the subject of syncope, Cullen has been mistaken. The brain during such time, continues in action as usual.

5thly, The numerous phenomena of apoplexy, and epilepsy, and concussion, &c. do certainly all of them tend to shew, how independent the heart is of the brain.

6thly, Every organ which is subject to the direct influence of the brain, is for that very reason an organ of volition. Now, I should suppose, that few persons of the present day, would be inclined to maintain with Stahl, that the heart is among the number of such organs. What would life be, were we able at will, to suspend the action of the organ, by which the system is animated? From simple observation, then, we might conclude, that it is not immediately that the heart ceases to act, when the functions of the brain are interrupted, but this fundamental datum of physiology and pathology, we shall further establish, upon actual experiment.

1st, If the brain of an animal be exposed, and irritated either with mechanical or chemical agents, a variety of alterations will, indeed, be produced in the organs of the animal life, but none in the heart, so long as the muscles of the breast continue to perform their functions.

2dly, Experiments made in the same manner upon the spinal marrow of the neck, present the same results.

3dly, If the eighth pair of nerves be irritated, the movements of the heart will not be accelerated; they will not be arrested if these two nerves be divided. In all these experiments, however, we must be careful to make a proper distinction between the emotions and passions of the animal, and what it really suffers from the experiment.

4thly, The nature of the great sympathetic nerve, I suppose to be known;* now if the same experiments be

* Physiologists have paid much attention to the great sympathetic nerve. They have made, in relation to its uses, many conjectures but few experiments; so that we have not on this subject any very precise notions. The deep situation of the ganglions renders them almost inaccessible, the superior cervical is almost the only one that can be taken out without producing death. M. Dupuy, Professor of the Veterinary School at Alfort, has discovered a method by which he can remove them with ease. We shall now relate some of his observations.

"*1st Experiment.* The first experiment was made on a young and vigorous horse, who had been treated for the glanders; it soon appeared that he was not affected with it, and that it was merely the caries of a tooth that had led to the belief of the existence of the disease.

"On the 24th of June his left guttural ganglion was extirpated. Soon after the operation, the eye of that side appeared to be made on the cardiac branches of this nerve, as were made upon the eighth pair, the same results will follow.

more sunk in its socket, the eyelids were swelled and the pupil contracted.

"On the 28th of June the sub-lingual ganglion appeared swollen, hard and attached; a discharge of fetid, greyish matter was discovered in the nostril of the same side.

"On the 29th of June, the wound suppurated copiously.

"From the 30th of June till the 16th of July the wound advanced rapidly towards cicatrization.

"From the 18th of July to the 15th of August the animal continued in the same state of health.

"On the 15th of August, the right guttural ganglion with a portion of the nerve was removed; this operation was followed by the same phenomena as the preceding, with this difference, that two days after the animal could not swallow water, it run out at the nostrils. There was in fact a communication between the nostrils and mouth from the caries of the back molar tooth, the roots of which were opposite the maxillary sinus, that had an opening into the nostril; the voice was lost.

"On the 20th of August, he was much emaciated, with the skin dry and adherent; the cheeks, below the jaw, were constantly moistened with sweat, which had been observed for twelve or fifteen days. The wound of the right side remained fistulous; the skin was covered with scurf, the sheath and scrotum, as well as the hind legs, were oedematous; the animal died. Nothing remarkable was discovered on dissection. Below the sub-occipital foramen the great sympathetic was slightly swelled, in the form of a knot, in the place where the division had been made."

"*2d Experiment.* On the 26th of April, the right guttural ganglion, with a portion of the nerve, was removed from a sound horse, four and a half years old, strong and in good condition. The ganglion of the left side was first a little mutilated, and the nerve was removed posteriorly to the extent of thirty three centimetres. The animal did not manifest so much pain as might have been expected.

"The conjunctiva soon became red and the eyelids partly covered the eyes; the respiration became painful and loud; the pulse was hard, strong and frequent. The animal refused all food, and drank with great difficulty.

"This state continued till the 10th of May following. The two wounds were almost healed; the animal eat and drank well; but the

I do not offer in detail the whole of these experiments; the greater part of them are well known: I was induced to repeat them, as authors are not agreed upon their consequences.

The experiments of galvanism, are well calculated to throw light upon the relations existing between the heart and the brain; these I have taken care to repeat with the utmost exactness, and whatever authors may have advanced, they are all in favour of the above opinions—for 1st, If the galvanic apparatus be applied to the brain, and to the heart, and inferior extremities of a frog, and the communication made between the metals, there will constantly be seen a strong contraction in the muscles of the limb, and little or none in the heart. The same will be the case, to whatever voluntary muscle the zinc be

hind legs and scrotum were still so much swollen as to interfere with his walking; the conjunctiva remained red and the pupil contracted.

"Towards the 13th of May the skin became adherent and covered with scurf; the cutaneous respiration was nearly destroyed.

"On the 25th of May, the swelling of the legs and the scrotum became considerable, notwithstanding the frictions with water and turpentine, which were made several times a day since the 13th; he could, with difficulty be got out of the stable to be examined. The pulse retained its hardness and frequency. The dung was hard, black and small.

"During the month of June the phenomena were similar to those we have enumerated; the swelling of the scrotum and the legs resisted the tonic and stimulating applications.

On examining the body, the ends of the nerves that had been drawn out were found swollen as in the first horse. Similar results have been obtained in all the other experiments that have been made on this subject. It may be said in conclusion, that the phenomena which appear after the removal of this ganglion, and which do not depend on the operation, are the contraction of the pupil, the redness of the conjunctiva, general emaciation, accompanied with swelling of the legs, and a scurfy eruption which ultimately affects the whole cutaneous surface.

applied. 2dly, The same results will be had, on the communication being made between the metals applied on the one hand to the spinal marrow above the giving off of the sympathetic, and on the other hand to the heart, and any of the voluntary muscles.

3dly, On establishing a communication between the metals applied to the cardiac nerves, and to the heart of the animal, there has been no contraction in the heart. In all these essays, the natural disposition between the parts which serve to unite the two organs, is preserved: there are other experiments which consist in detaching the heart from the breast. 2dly, In placing two points of its surface in contact with two different metals. 3dly, In making the communication between them with a third. From thise xperiment, Humboldt and other philosophers have procured contractions, but I have taken care to repeat it with the greatest accuracy, and must assert, that I have seen little or nothing of the kind; indeed, if I had, I should have concluded nothing from it; for it appears to me, that to decide upon the influence of the brain over the heart, a portion at least of the nervous system, should be in contact with one of the metals.

I shall now pass to my experiments on red and warm-blooded animals. They are necessary for the decision of the question before us, as the mode of contractility in these animals differs much from that of the animals submitted to the experiments already mentioned.

1st, In the winter of the year 1798, I was authorzied to make different essays on the bodies of persons who had been guillotined. I had them at my disposal thirty or forty minutes after they had undergone the punishment. In some of them, all mobility was extinct; in others, this property could be reanimated in all the muscles by the common agents, and in those of the animal life, by galvanism especially.* Notwithstanding which, I could never occasion the least motion, in applying the apparatus

* Galvanic experiments have at different times been made on the bodies of those who have been executed. Vassali, Julio and Rossi made a great number of them at Turin; but the piles that were then used were very weak compared with those that are now employed. In the experiments made at Newgate on the body of a criminal, the limbs were violently agitated, the eyes opened and shut, the mouth and the jaws moved in every direction, and the face was thrown into the most frightful convulsions. The last and most complete experiments, that we know of, were made at Glasgow in November 1818 by Dr. Andrew Ure. He used for these experiments a battery composed of two hundred and seventy pair of plates four inches square, with communicating wires, and so arranged that they could be insulated for the purpose of applying the electricity in a more convenient manner.

The subject, on whom these experiments were made, was of middle heighth, about thirty years of age and of an athletic constitution. He was on the gallows almost an hour, and he was not convulsed after being hung, whilst a robber executed at the same time was violently agitated for a considerable time. He was carried to the anatomical theatre of the university, about ten minutes after he was removed from the gallows. His face had a perfectly natural appearance being neither livid nor swollen, and the neck was not dislocated.

About five minutes before the arrival of the police officers with the body, the battery was charged with diluted nitro-sulphuric acid, which quickly put it in a state to exert an intense action.

1st Experiment. A large incision was made immediately below the occiput. The posterior half of the first vertebra was then removed and the spinal marrow laid bare, at the same time a considerable incision was made in the great glutæus muscle, in order to expose the sciatic nerve. A slight incision was made in the heel; no blood escaped from any part. A wire which communicated with one extremity of the battery was put in contact with the spinal marrow, whilst the other was applied to the sciatic nerve. All the muscles of the body were in an instant agitated with convulsive motions which resembled a violent shuddering. The strongest convulsions were on the left side; at each time of renewing the electric contact by moving the second wire from the haunch to the heel the knee being previously bent, the leg was either to the spinal marrow and the heart, or to this latter organ and the nerves, which it receives from the

thrown out with so much force, that it threw down one of the assistants who in vain endeavoured to prevent the extension.

2d Experiment. The left phrenic nerve was laid bare towards the external edge of the sterno-thyroideus muscle, three or four inches above the clavicle; as this nerve goes to the diaphragm, and as it communicates with the heart by the eighth pair, it was expected, that by throwing the galvanic fluid through it, the action of respiration would be renewed. In consequence a small incision having been made under the cartilage of the seventh rib, the point of an insulated wire was placed in contact with the diaphragm, whilst the other was applied to the phrenic nerve of the neck. This muscle, the principal agent of respiration, contracted immediately, but with less force than was expected. As I knew by numerous experiments that we could produce the most powerful effects from the galvanic fluid, by leaving the extreme communicating wires perfectly in contact with the parts on which we wished to operate, whilst, in order to complete the electric chain, we carried the end of the wires the length of the plates, into the last trough of one of the poles and immediately plunged the other wire into the last cell of the opposite side, I had recourse to this measure without loss of time. The success was truly astonishing; instantly commenced a strong and laborious respiration. The chest rose and fell; the abdomen was pushed forward and then flattened, and the diaphragm contracted and relaxed. All these motions appeared without interruption as long as I continued the electric excitement.

In the opinion of many scientific persons who were witnesses of this scene, this experiment was perhaps the most striking that had ever been made with an electrical apparatus. It should be recollected that during half an hour at least, before this, the body had been nearly exhausted of blood and the spinal marrow had been much lacerated.

No pulsation could be perceived either in the heart or at the wrist.

3d Experiment. The suborbitar nerve was laid bare at its exit from the suborbitar foramen. One of the conducting wires was applied to the nerve and the other to the heel; the most extraordinary grimaces were produced. All the muscles were put simultaneously in action in a frightful manner; rage, horrour, despair, anguish and frightful smiles united their hideous expression in the face of the assassin. At the sight of this, many of the spectators were obliged to leave the room and one of them fainted.

4th Experiment. The last galvanic experiment was made by transganglions of the sympathetic, or the par vagum. Nevertheless, the common mechanical excitant, immediately applied to the fleshy fibre, occasioned its contraction. Could this have happened in consequence of the separation of the nervous fillets from the brain? assuredly not; because the voluntary muscles were equally separated from it, and yet affected strongly. If any doubt remain, the following experiments will clear it up.

2dly, In dogs and guinea pigs, I have repeatedly applied the metals, first to the brain and the heart, then to the trunk of the spinal marrow, and the heart; then to the par vagum and the heart. The communication being made, was followed by no apparent result.

3dly, On making the communication between the metals, when applied to the cardiac nerves and the heart, there was no very sensible motion.

4thly, Humboldt has asserted, that when the heart is speedily detached with some of its nervous threads about it, a contraction may be excited, by arming the nerves with a metal, and then by touching this metal with another. I have many times tried this experiment in vain. I confess, however, that once it appeared to me to succeed.

5thly, On the contrary, I have almost always succeeded in producing contractions in the heart, by cutting it away from the breast, and making a communication between a couple of metals, applied to different points of

mitting the electric fluid from the spinal marrow to the cubital nerve near the elbow; the fingers moved quickly like those of a performer on a violin; one of the assistants who endeavoured to keep the hand shut, found that it opened in spite of his efforts. A wire was applied to a slight incision made at the end of the first finger; the hand had been previously shut; the finger was instantly extended, and, after a convulsive agitation of the arm, the dead man seemed to point his finger at the spectators, some of whom thought that he had come to life.

An hour was consumed in these experiments.

its surface. This, if I am not mistaken, is the only means of evidently producing the phenomena of galvanism in this organ, but with respect to our present question, the experiment is wholly inconclusive.

All these experiments I have repeated many times, and with the most scrupulous precautions, nevertheless I do not pretend to call in question the reality of those results, which other physicians have remarked. It is well-known how very variable those experiments are, which have the vital powers for their object. Besides, in admitting even these different results, I do not see how it is possible to refuse acknowledging, that with respect to the stimulus of galvanism, there is a wide difference between the susceptibility of the muscles of the animal life, and those of the organic life. Again, supposing that the galvanic phenomena were the same in both sorts of muscles, the fact would prove nothing more, than that these phenomena with regard to their succession, follow laws directly the contrary of those, which are displayed in the phenomena which take place, when any common cause of irritation is applied to the nerves and their corresponding muscles.

The proofs adduced, will allow us to conclude, that the brain exercises no direct influence over the heart, and consequently, that when it ceases to act, the functions of the latter must be interrupted indirectly.

II. *In case of lesion of the brain, is the death of the heart occasioned by that of any intermediate organ?*

When the brain dies, the heart dies, but not directly. There must be some intermediate organ then, the death of which occasions that of the heart.* That intermediate

* It is shewn by the beautiful experiments of M. Legallois, that the heart derives the principle of its forces from the spinal marrow, and

organ is the lungs. In this sort of death, the following is the series of the phenomena which may be observed.

1st, The cerebral action is interrupted. 2dly, The action of all the muscles of the animal life, and consequently of the intercostals and diaphragm, is annihilated. 3dly, The mechanical functions of the lungs are suspended. 4thly, The like ensues with respect to their chemical functions. 5thly, The fibres of the heart are penetrated with black blood. 6thly, The fibres when so penetrated, die.

Such sort of death then, has much resemblance with that which is occasioned by the different asphyxiæ. It is only more sudden, and that for reasons which I shall presently point out. The following experiments are an evident

from the whole spinal marrow, since the destruction of one of its three portions can arrest completely the circulation. The destruction of the spinal marrow does not entirely annihilate the motions of the heart; but it weakens them sufficiently to prevent the circulation, and this weakening is so much the greater, as the portion of spinal marrow destroyed is larger. It may be presumed from this, that notwithstanding the weakening which follows the removal of a part of this marrow, the circulation may still continue if we lessen the sum of the forces which the heart must expend to maintain it. For this it is only necessary to diminish by ligatures on the arteries, the extent of the circle to which the heart distributes the blood. This conjecture is confirmed by experiment. It has been seen, for example, that the destruction of the marrow which is very suddenly fatal in full grown rabbits, ceases to be so, if before doing it the abdominal aorta is tied between the coeliac and the superior mesentric arteries. The application of the same principle to other parts of the body leads to a still more surprising result, it is this, that in order to support life in rabbits of a certain age, after having destroyed the cervical marrow, it is necessary first to cut off the head. They will be completely dead if the marrow be destroyed before they are decapitated; this arises from the fact, that by cutting off the head all this part is taken out of the domain of the circulation, and that by it the heart having need of less force to continue its function, we can weaken it by the destruction of the cervical marrow without its ceasing to perform it.

proof that the phenomena take place as I have described them to do.

1st, I have always found black blood in the red-blooded system of all animals, killed by concussion or compression of the brain; the heart livid, and the different surfaces coloured as in asphyxia.

2dly, I opened the carotid artery of a dog; the red blood instantly gushed out, but was immediately suppressed, and the artery tied. I then killed the creature, by striking him with violence on the occipital bone.* The animal life, and consequently both the mechanical and chemical functions of the lungs, were suddenly suppressed. The artery was then united. It poured forth the black blood with a feeble jet, for some little time, and after some minutes, the heart entirely ceased to move.

3dly, I have always obtained a similar result in opening the arteries of different animals which I afterwards killed, either by dividing the marrow between the first vertebra and occiput, or by strongly compressing the brain, which I had previously exposed.—It is thus also that animals perish, by the carotids of which a deleterious substance has been injected.

4thly, The preceding experiments explain the reason why the blood is black which flows from the arteries of animals, which are bled in our slaughter-houses, after having been knocked in the head. If the blow has been violent, the blood issues such as it was in the veins, but if the action of the diaphragm and intercostals has only been weakened by the blow, the redness of the blood is only diminished.

* When an animal is thus struck, it is not certain that the concussion has not extended its effects upon a greater or less part of the spinal marrow; and it is not known consequently if the motions of the heart would not cease, even when asphyxia might be prevented by means of artificial respiration.

The state in which the respiration may be (and it is altered from a variety of circumstances during profuse hemorrhagy) occasions a great variety in the colour of the arterial blood: hence we have the reason why it is found of so many different shades in the great operations of surgery. At the beginning of these, it often flows out quite red; at the end of them, is sometimes almost black. The easy or embarrassed state of the respiration of the patient, is the occasion of these varieties. This I have frequently remarked, when attending Desault, and was often struck with the appearance, before I knew the cause of it.

I have never found any relation whatever, between the obscure colour of the blood, and the compression exercised above the artery, as some have asserted to take place. There is, indeed, a connection between the colour and the impetuosity of the jet, but the reason of this is evident to any one who has read the foregoing pages.

To return to the point of doctrine on which we are at present occupied, I am persuaded from the considerations and experiments which are adduced in the course of this chapter, that the manner in which the heart ceases to act, when the cerebral functions are suspended, can no longer admit of a doubt, and that we may resolve the question proposed, in affirming that under such circumstances, the death of the heart is occasioned through the medium of that of the lungs.

There is this difference, then, between the death of the heart, in consequence of that of the brain, and the death of the brain in consequence of that of the heart, that the one is indirect, the other direct, as we have already seen. If some men, as Stahl asserts, have really been able to suspend the movements of the heart, the fact is not a proof of the influence of the mind over the muscles of the organic life, but of its power over the mechanical, and consequently, the chemical phenomena of respiration.

In red and cold-blooded animals, the death of the heart does not succeed the death of the brain so quickly as it does in red and warm-blooded animals. Cut off the head of a frog, and the heart will continue to beat for some time afterwards. This phenomenon will be easily accounted for, if we recollect that respiration with these animals may be suspended a length of time, without arresting the movements of the heart.

In fact, as the heart dies only because the lungs die in the first place, when the cerebral functions are interrupted, it is plain that there ought to exist between the violent death of the heart and that of the brain, an interval nearly equal to that during which, in the natural state, there may be a suspension of respiration.

CHAPTER XII.

OF THE INFLUENCE OF THE DEATH OF THE BRAIN OVER THAT OF ALL THE ORGANS.

When the brain dies, the animal life dies, for the functions of this life, either directly or indirectly, have their seat in the brain. It is manifest, that all the operations and affections of the mind, together with sensation, locomotion, and the voice, must be put an end to in such case. The difficulty then respects the functions of the organic life.

I. *Is the interruption of the functions of the organic life a direct consequence of the cessation of the cerebral actions?*

We shall here adduce both observation and experiment to prove, that the internal functions are all of them, as well as the action of the heart, withdrawn from the immediate influence of the brain.

1st, There are a number of diseases affecting the brain, which occasion so general a suspension of the animal life, as to leave neither sensation nor voluntary motion, excepting some feeble oscillations of the intercostals and the diaphragm. In this state the individual has lost the half of his existence, but the one half composed of the organic functions, continues in the meanwhile to subsist, and in many cases with energy. This phenomenon is exemplified continually in apoplexy, in concussion of the brain, and extravasation of blood upon its surface.

2dly, During sleep the secretions certainly go on, though Bordeu insists upon the contrary opinion, with the view of proving the influence of the nerves over the glands. During a state of sleep, digestion goes on as usually it does. The exhalations of the body are made with perfect freedom, and often augmented beyond their natural quantity; the process of nutrition continues to be effected, and is probably under such circumstances, increased. There are many proofs in favor of this opinion; but a state of sleep is a state of collapse in the brain. Then, neither is the relaxation of the functions of the internal organs the consequence of a relaxation of action in the brain, nor the death of the former the immediate effect of the death of the latter.

3dly, The sleep of animals, which pass a certain part of the year in a state of torpor, is a very strong proof of the co-existence of a suspension of the cerebral functions, with a permanent action of those of the organic life.*

4thly, In the different palsies; in those for instance which affect the lower limbs, and the viscera of the pelvis, in consequence of some concussion or compression of the medulla spinalis, the communication of the paralyzed parts with the brain, is either entirely cut off, or only enfeebled. It is entirely interrupted when all feeling and power of moving have ceased—it is enfeebled, when the one and the other of these properties are only enfeebled. But in these two cases the general and the capillary circulations continue. The exhalations from the cutaneous surface and in the cellular substance, are made as usual; the process of absorption goes on, for without absorption, we should soon see dropsy. The secretions also are effected, for nothing in such sort of palsy is more common than a copious secretion of mucus from the bladder. As for nutrition if it be diminished in energy, the process is certainly never entirely arrested.

5thly, Spasms and convulsions, which proceed from an unnatural energy of the cerebral action, have little influence over the exhalation, secretion, and nutrition of the

* When two states, which are not perfectly similar, are designated by a common name, it is very difficult, whatever care may be taken to distinguish them, not to apply to one something which exclusively belongs to the other. This is perhaps one of the most frequent sources of our errours. In this case, for example, it does not seem that there is a great inconvenience in designating by the word sleep the state of torpor of certain animals during a part of the year. It is well known that we understand by it altogether a different thing from the sleep, which in warmer seasons of the year, comes on periodically every day; yet in consequence of the identity of the name, we are disposed to admit identity of character and to infer from one respecting the other.

parts in which they make their appearance. The trouble and excessive agitation of the animal life of such parts, compared with the calm of their organic life, are facts well worthy of remark.

6thly, Fœtuses without heads, in the uterus, possess as active an organic life, as those which have no defect of conformation whatever, and sometimes at the time of birth, are monstrous even in bulk; this circumstance I have frequently had occasion to observe at my amphitheatre; the functions of nutrition then and circulation may take place with activity, though deprived of the influence of the brain:

7thly, In animals, which have no cerebral mass, and in those (the polypes for instance) where not even a nervous system is apparent, these organic processes are admirably well conducted,* the greater part of them indeed are common to the vegetable, and the animal.

8thly, If the different proofs, which Bordeu has given of the influence of the brain over the functions be well examined, it will seem that no one of them is decisive. The sudden interruption of the secreted fluid, in consequence of the division of the nerves of the part, would be the only proof which I should be inclined to admit as positive. Now I am not acquainted with any means of making such division with exactness. We have heard much of an experiment of this nature upon the parotids; but the disposition of the nerves distributed to these glands is such, that I have not been even tempted to

* What is the circulation of an animal which exhibits no trace of vessels? what inferences can be drawn for man from the mode of nutrition of a polypus? what relation can be established between the complex function which presides in the mammalia over the support of the organs, and the kind of imbibition by means of which the zoophyte is developed and preserved?

repeat the experiment. The testicle is better adapted for the attempt, and accordingly without touching the vessels, I divided the spermatic nerves, but an inflammation and a deposit of matter took place in the gland, and with respect to the secretion of the semen, I could not judge of the effect of the division of the nerves. But here this very inflammation coming on without the influence of the brain, appears to me to infer a possibility of the seminal secretion under the same circumstances. In this experiment, the spermatic artery cannot be separated from the plexus which it receives from the great sympathetic, so intricate is the network of these nerves about it; their division however is of little consequence, as they come from the ganglions. It is easy to break off all communication with the brain, by destroying the lumbar fillets of nerves.

I might add a number of other considerations to the above, but here I have to remark that the distinction of the sensibility and contractility into their two kinds is particularly worth attention. In fact, the idea of sensibility in our usual way of seeing things, suggests the idea of the nerves, the nerves again make us think upon the brain, we associate the three ideas, but excepting for the animal life they should not be associated. In the organic life, at least their union is not immediate.

I do not mean to say that the cerebral nerves have no influence whatever over the organic sensibility, but I maintain that such influence is not direct and not of the nature of that which is observed in the animal sensibility.

Many authors have already discovered a number of difficulties resulting from the opinion which makes the nerves the exclusive seat of sensibility, they have even sought for other means of explaining the phenomena of great living bodies. But of its agents we know as little as we do of its nature, and have no means of elucidating questions of this sort. Let us be contented with analyzing, collecting and comparing facts with seizing their general results; the aggregate of these researches will compose the true theory of the vital powers; the rest is only conjecture: but besides the considerations which I have offered, there is another which manifestly goes to prove that the organic functions are not under the immediate influence of the brain, and this is, that the viscera, which perform such functions do not receive their nerves from the brain but from the ganglions.

This anatomical fact is observable in the liver, the kidney, the spleen, pancreas, intestines, &c. even in the organs of the animal life there are nerves which serve for the external, and nerves which serve for the internal functions. In such the former come directly from the brain, the latter from the ganglions. Thus the ciliary nerves, which come off from the opthalmic ganglion, are those which preside over the secretions and nutrition of the eyes, the optic nerve which is derived from the brain is the nerve of vision.* In the same way the olfactory nerves of the pituitary membrane are the agents by which we have the perception of odours, the threads which come off from the ganglions of Mekel, relate only to the organic phenomena of the membranes.

Now the nerves of the ganglions cannot transmit the action of the brain; for we have seen that the nervous system derived from these bodies should be considered as entirely independent of the nervous system of the brain; and that the great sympathetic does not derive its origin

* The external ciliary nerves only come from a ganglion. The internal ciliary ones which have precisely the same distribution and serve also very probably the same uses, come from a cerebral nerve, from the nasal branch of the ophthalmic.

from the brain, from the spinal marrow, or from the nerves of the animal life; but from the ganglions exclusively; this nerve indeed does not exist, it is only the aggregate of so many small nervous systems as there are ganglions, which are the particular centres of the organic life, just in the same way as the brain is the great and only centre of the animal life.

To establish it as a fact that the great sympathetic such as it is understood does not in reality exist, I might add a number of proofs to those, which I have already mentioned. The nervous communications, which are taken for it, are nothing more than accessories to the system of the ganglions; for 1st, These nervous communications, as Cuvier has observed, are not met with in the necks of birds; between the upper cervical and first thoracic ganglion there is no vestige of a sympathetic. In birds then, the upper cervical ganglion is that which in man the opthalmic ganglion, the ganglion of Mekel and others are. This disposition, which is natural in birds, agrees with what I have sometimes observed in the human subject between the first lumbar and the last thoracic ganglions, as well as between the lumbar and sacral ganglions themselves. 2dly, In many instances there are no ganglions in the spot where the pretended sympathetic nerve communicates with the spinal marrow. This may be seen in the human neck, and in the abdomen of fish, but such disposition should be thus regarded. The inferior cervical ganglion furnishes a great branch which ascends to the superior cervical ganglion, and establishes between the two a direct communication; but in ascending it distributes many branches to each of the cervical nerves, which form a secondary communication.

If we reflect on these considerations, together with those which have been already offered, we shall be more and more convinced—1st, That the great sympathetic is only an assemblage of small nervous systems, having each of them a ganglion for its centre, and all of them independent of each other, though generally communicating with the spinal marrow and between themselves. 2dly, That the nerves belonging to these small systems, cannot be considered as a part of the great nervous system of the animal life. 3dly, That the organs, which are provided exclusively with the nerves, are not under the immediate influence of the brain.

Notwithstanding which, we must not suppose that all the organs which serve for the internal functions, receive their nerves exclusively from the ganglions: many of these organs are furnished from the brain, and yet from experiment, it is found that they are not under the immediate influence of the brain.

As yet we have only observation and reasoning for the basis of the important principle which we are labouring to establish, namely, that the organic functions are not directly put a stop to in consequence of the death of the brain; but experiments upon living animals are not a less evident demonstration of this principle.

1st, I have always observed, that in producing palsy or convulsion, I have never been able to impair in any very sensible or sudden manner, either the exhalation, the absorption, or the nutrition of the convulsed or palsied part.

2dly, It has been for a long time known, that no spasm of the muscular fibres of the stomach, bladder, or intestines, can be produced by irritating the nerves of the ganglions which go to these organs.

3dly, The division of the nerves of the ganglions, will not immediately paralyze the hollow organs. Their vermicular motions continue for a long time after the experiment.

4thly, With respect to the stomach, intestines, bladder and uterus, I have repeated the galvanic experiments which, with respect to the heart, have already been mentioned at length; but never could obtain contractions.*

5thly, The same experiments being made upon the organic muscles, and the great sympathetic nerve of a dog, there was no contraction.

6thly, The issue of the latter operation may be easily conceived, according to our manner of regarding things. In fact, the ganglions, which are situated between the gastric organs and the nervous trunk of the chest, might possibly have interrupted the series of the galvanic phenomena. With a view, then, to remove all doubt of this kind, I exposed the nerves, which go from the ganglions immediately to the stomach, bladder and rectum, and in this way galvanised the organs but no contraction appeared to me to be the result of the experiment; at least no contraction, which I could suppose to be the effect of galvanism, for here I cannot too much recommend a proper distinction to be made between that which should be the effect of this fluid, and that which results from the mechanical contact of the metals.

7thly, These experiments are not easily made upon the intestines, on account of the tenuity of their nerves; but as these nerves compose a very perceptible plexus about the mesenteric artery, the intestine may be galvanized by surrounding the artery with one of the metals; while the other is placed under the intestinal tube. This experiment I have made, but could not obtain any sensible result.

* The galvanic stimulus usually produces very evident effects upon the contraction of the intestinal tube; these motions are less evident in the stomach than in any other part of the canal; but the same difference is always observed whatever be the stimulus employed.

8thly, The preceding essays were made upon warm and red-blooded animals. Similar attempts were repeated on cold and red-blooded animals, but with no effect.

9thly, The nerves which immediately supply the gastric organs of the frog, are so delicate as to make it an extremely difficult matter to get them into proper contact with the zinc: a small contraction of the stomach was, however, obtained by Jadelot on operating directly on these nerves; but this contraction was similar, no doubt, to those which I have so frequently observed in other experiments, and not to be compared to the astonishing effects which are observable in the voluntary muscles. I shall conclude, therefore, that with respect to the galvanic phenomena, there exists a wide difference between the muscles of the animal life and those of the organic life.

I have now collected proof enough, I trust, for resolving, with certainty, the question proposed in the above chapter, and for establishing it as a fundamental principle—1st, That the brain does not directly influence the organs and the functions of the internal life; and 2dly, That, therefore, the interruption of these functions, in case of any great lesion of the brain, is not an immediate effect of such lesion.

Nevertheless, I am far from considering the cerebral action as foreign entirely to the organic life. I only maintain that its influence upon it is indirect, and as yet but little known. I have been somewhat prolix upon this subject; for certainly nothing in medicine is more vague than the sense which is commonly attached to the words *nervous action*, *cerebral action*, &c. There is never a proper distinction made between that which belongs to one life, and that which is the attribute of the other. Cullen, in particular, may be reproached with having exaggerated the influence of the brain.

II. *Is the interruption of the functions of the organic life, the indirect effect of the cessation of the cerebral action?*

The organic life continues to subsist for a certain time, after the apparent death of the individual. There must be some intermediate agents then, the cessation of the action of which, occasions the death of the inward organs. Such agents are chiefly the mechanical organs of respiration. The series of the phenomena are the following:

1st, The cerebral actions are interrupted.—2dly, The mechanical functions of the lungs are put an end to.—3dly, There is an annihilation of their chemical functions.—4thly, The black blood circulates in all the parts.—5thly, The movement of the heart and the action of all the parts is weakened.—6thly, Suspended.

All the inward organs then, die nearly as they do in asphyxia; that is to say—1st, Because they are penetrated by the black blood.—2dly, Because the circulation ceases to communicate that motion which is essential to their life.

Nevertheless, there are many differences between death from asphyxia, and death from lesion of the brain. 1st, The animal life in the latter sort of death, is generally interrupted at the very instant of the shock or blow. In the former it is terminated only in proportion as the black blood penetrates the substance of the brain.—2dly, In the greater number of the asphyxiæ, the circulation does not immediately cease, the blood is only gradually blackened, and continues for some time to be moved onwards by the agitation of such parts as are still under the influence of the brain. On the contrary, in lesion of the brain, the interruption of respiration is sudden; the blood also loses its red colour at once: on the other hand, the animal life being suddenly arrested, the organs of volition become immovable on the spot, and are capable no longer of favouring the motion of the blood. This remark is particularly applicable to the breast, the parietes of which facilitate very much the pulmonary circulation, and even the movements of the heart by their rise and fall, for in such alternation of motion consists the true influence which the circulation receives from the respiratory process.

But after all, these two sorts of death may be more or less similar to each other according to the way in which they happen. The differences which I have pointed out are by no means general. Thus, when asphyxia is sudden, as when for instance the air of the lungs is pumped out with a syringe, there are neither livid spots, or fulness of the lungs to be met with. The circulation ceases quickly, and the phenomena of death are such as are observable when the brain is suddenly destroyed.

On the contrary, if the death of the brain be slow, and the process of respiration for a certain time continued, the capillary system of the lungs will be gorged with blood, and the general capillary system be filled also. The circulation in such case will be slow to cease, and the phenomena of death like those of many of the asphyxiæ. Thus the promptitude or slowness of death, proceeding from lesion of the brain, will occasion all the differences.

It has been often a question in what way criminals die, who are hanged. In some, the vertebral column is luxated, and in others, want of respiration is the cause of death.* But whenever there is luxation, there is at

* Death does not always take place in the same way. It has been remarked, for example, that those who were hung at Lyons died quicker than those who were hung at Paris. In seeking for the cause of this

the same time asphyxia, and in such case asphyxia is produced, both because the pressure of the cord intercepts the passage of the air, and because the intercostals and diaphragm are paralyzed.

From what I have now said, a comparison may be made between the three kinds of death upon which I have expatiated. This comparison, according to my ideas, is of importance: I shall give some features of it. Generally speaking, there is a greater similarity in the two modes by which the death of the brain, or that of the lungs produces the death of the organs, than between either of these modes, and that, where the death of the heart is followed by the same effect.

But 1st, There is always black blood in the red-blooded system, when death begins either by the brain or the lungs. When the functions of the heart are suddenly suspended, the arterial system contains a portion of red blood only.

2dly, In the two first cases, the circulation continues for awhile; in the third, it is immediately suppressed.

3dly, When the death of the organs is a consequence of the death of the heart, they die, because they cease to receive that excitement to which they are accustomed from the motion of the blood. When their death is produced by that of the brain or lungs, they die not only because they lose the excitement above-mentioned, but because they are penetrated by a fluid which is incapable of keeping up their actions, &c. The reader will easily finish the parallel which I have thus begun.

difference, it was ascertained that in those who were executed at Lyons there was almost always a luxation of the first or the second vertebra, which was owing to a rotatory motion, which the executioner gave to the criminal in throwing him from the scaffold. The death was quick, because it was produced by compression or laceration of the spinal marrow; it was slower in the other case in which it was only the result of asphyxia.

In red and cold-blooded animals, the death of the organs succeeds much more slowly to that of the brain, than in red and warm-blooded animals. We cannot assign the reason of this fact, because we do not know the difference of the arterial blood from the venous blood of these animals, nor the effect which is produced on their organs by the contact of either sort of blood with them.

When reptiles remain for a length of time under water, does the arterial blood become black from want of respiration? is the influx of such blood into their organs, pernicious or not?* or is there a sufficient quantity of air contained in the large vesicles of the lungs of these animals to oxydate their blood for a length of time, as but little blood is capable of passing into the pulmonary

* It appears by the beautiful experiments of M. Edwards that frogs can live but a very short time in water deprived of air by boiling. Immersed in a small body of water containing air they soon die, no doubt after they have exhausted the air held in solution in the water. They can on the contrary live an indefinite time in this state of immersion, if care be taken to renew the water sufficiently often. The same thing happens, and still more certainly, if they are immersed in running water.

It is not by passing the water through the lungs, as the fish does through the branchiæ, that the frog obtains the air held in solution by the water in which he is immersed, the skin is in this case the sole respiratory organ. M. Edwards is satisfied that this mode of respiration is not sufficient to support life, except between certain limits of temperature; a frog immersed in a volume of water which is not changed, continues to live so much the longer as the temperature of this fluid approaches nearer 32°. At this degree frogs are not torpid, as might be supposed, only their motions are slower.

As long as the animal immersed in the water remains perfectly alive, which may be known by the vivacity of his motions, it is certain that the respiratory phenomena continue to be performed by him; we see in fact on the membranes in the interstices of the toes, the vessels filled with vermilion blood. When the black colour begins to appear, the animal soon becomes immoveable and insensible.

artery, which is only a branch of the aorta. The latter opinion appears to be confirmed by the experiment of injecting the lungs of a dog with a large quantity of air, in which case the blood of the creature is reddened for a greater length of time. But all these questions, notwithstanding the essays of Goodwyn, require much elucidation.

CHAPTER XIII. - 334

OF THE INFLUENCE OF THE DEATH OF THE BRAIN OVER THAT OF THE BODY IN GENERAL.

From the consideration of what has been said in the preceding chapter, nothing can be more easy than to form an accurate idea of the manner in which the phenomena of general death, commencing by the brain, are concatenated. The series is as follows:

1st, The cerebral action is annihilated. 2dly, There is a sudden cessation of sensation and voluntary motion. 3dly, A simultaneous paralysis of the intercostals and diaphragm. 4thly, An interruption of the mechanical phenomena of respiration and the voice. 5thly, An annihilation of the chemical phenomena of the lungs. 6thly, A passage of black blood into the arteries. 7thly, A slowness of circulation owing to the influx of such blood into the arteries, and the absolute immobility of all the parts, of the intercostals and diaphragm in particular. 8thly, The heart dies and the general circulation ceases. 9thly, The organic life vanishes. 10thly, The animal heat, which is the product of all the functions, disappears. 11thly, The white organs die.

Though in this kind of death, as well as in the two preceding kinds, the functions are suddenly annihilated; the parts retain, for a certain time, a number of the properties of life. The organic sensibility and contractility, continue for some time, to be manifest in the muscles of the two lives; and in those of the animal life, the susceptibility of being affected by the galvanic fluid is very great in the muscles of the animal life.

This permanence of the organic properties, is nearly the same in every case; the only cause which affects it, is the slowness with which the phenomena of death have succeeded each other. In every case where their duration has been the same, whatever may have been the cause of death, experiments instituted upon these properties, are attended with similar results; for it is evident that concussion of the brain, luxation of the vertebræ, the section of the spinal marrow, apoplexy, compression of the brain, or inflammation, are all of them causes which are attended with a like effect.

The same, however, is not the case with respect to the asphyxiæ produced by the different gases. We have shown the reason of this in the more or less deleterious nature of the gases which produce asphyxiæ.

The state of the lungs also, is very various in the bodies of persons who have died from lesions of the brain. This organ is sometimes gorged and sometimes almost empty: it shews, however, whether the death of the individual has been sudden or gradual. The same indication may be had from the state of the exterior surfaces.

The death, which is the consequence of disease, commences much more rarely in the brain, than in the lungs. Nevertheless, in certain paroxysms of accute fever, the blood is violently carried to the head, and is the occasion of death. The concatenation of its phenomena, are then the same as take place in sudden death.

There are a great number of other cases besides those of fever, where the commencement of death may be in the brain, though the brain itself may not have been previously affected by the disease. In these cases, the state of the lungs is very various; but little can be learnt from it with respect to the nature of the disease. It is only an indication of the manner in which the functions have been terminated.