X. *On the Nature of Death.* *By* A. P. W. Philip, *M.D. F.R.S. L. & E. &c.*

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I NEED hardly say, that in such a communication as the present, I have no intention of entering into the part of the subject of this paper which may justly be termed metaphysical. The veil which separates it from experimental science must ever remain impenetrable, there being no source of information respecting it, but a direct revelation from the great Author of our being, or the instincts he has implanted in our nature, for all knowledge is not acquired. We come into the world with knowledge essential to our existence. The infant knows as well how to breathe and how to suck as the adult, and these acts depend as much on mental operations as those which are the results of experience. He perceives his wants, and he knows how to relieve them; and the extent to which this species of knowledge exists in some animals, whose reasoning powers are extremely limited, justly excites our wonder and admiration. They know what is essential to their condition with an accuracy which sets at defiance all the efforts of human reasoning, for their knowledge is the knowledge of their Creator.

To the physiological part of the subject alone I wish to direct the attention of the Society. It forms part of the same subject with the three last papers I had the honour to present to it, published in the Philosophical Transactions for 1831 and 1833; namely, the relation which the different powers of the living animal body bear to each other. In these papers I endeavoured to trace the nature of their influence on each other while their state of vigour remains; in the following paper I shall attempt to point out the manner in which they influence each other in their state of decay.

In the course of my Inquiry into the Laws of the Vital Functions, it became necessary to determine, with more precision than had been done, the line of distinction between the sensorial and nervous functions.

The function of the muscular system, from its nature and the peculiar structure of its organs, is readily defined; but in the nervous system we perceive more than one set of functions, and yet, both from the variety of ways in which they are interwoven, and from the peculiar mechanism of the active parts of their organs being so minute as to escape our senses and consequently the investigations of the anatomist, the difficulty of correctly distinguishing them is considerable. It is only by experiments instituted for the purpose, and founded on the very different nature of these sets of functions, that the line of distinction can be drawn.

In order to render the results more certain, I endeavoured to ascertain this line by two sets of experiments, conducted on different principles; the object of the one being

to ascertain what functions remain after the sensorial power is withdrawn, and of the other, what functions fail on withdrawing the nervous power; and in prosecuting this subject, I found it requisite to study the process of dying, to determine the steps by which the body of the more perfect animal becomes subject to the laws of inanimate matter.

The experiments by which this was more immediately attempted were not laid before the Society as were the other parts of the investigation. They are detailed at length in the second part of my Inquiry into the Laws of the Vital Functions. I have there, however, entered no further into the nature of death than was necessary for the purpose I then had in view. I am now about to compare the results of these experiments with those of others, made since the publication of that treatise, with a view, as far as experiment can apply to it, of explaining the nature of death.

It appears to me that the various facts ascertained in the course of the inquiries in which I have been so long engaged, throw light on this subject. I shall, as I proceed, refer to the passages, either in my papers in the Philosophical Transactions or my Inquiry into the Laws of the Vital Functions, where the proofs of the different positions I shall have occasion to state, will be found.

In the last of the papers above referred to, I had occasion to observe, that there is no question relating to the animal economy which involves a more general view of its phenomena than the nature of sleep. The nature of death also includes a general view of the functions of health, for such we shall find are the laws of our frame, that these functions alone necessarily lead to death; but the nature of death is a more complicated question. It includes the various ways in which the functions are influenced by disease, the effects of which are so numerous that they seem at first view a train of countless phenomena which defy all attempts to refer them to general principles.

I need not say that many advantages would arise from a correct knowledge of the immediate cause of death, and of the different sources from which the state that constitutes that cause arises. The most important would be, that it would give to the physician a clearer view of the tendencies of disease, and consequently of the indications of cure; but it would not be the least of its advantages, that it would tend to strip a change which all must undergo of the groundless terrors with which, we have reason to believe, the timid and fanciful have clothed it.

IT appears from the experiments in question, that in the more perfect animals there are three distinct classes of functions, the sensorial, the nervous, and the muscular, which, having no direct dependence, are yet, through their organs, dependent on each other; for the destruction of any one of these classes of functions more or less immediately destroys the organs of all.

We know that the immediate organs of the nervous and sensorial functions, although both residing in the brain and spinal marrow, are distinct sets of organs, because they

have not the same locality; the former, as appears from direct experiments, being distributed throughout the whole brain and spinal marrow, and, as far as experiment can determine, equally so, except that the lower part of the spinal marrow either partakes of them less, or they are there of less power*; while the latter, in all the more perfect animals, are chiefly, and in man almost wholly, confined to the brain; and because in disease we often see the functions of the one class greatly impaired without those of the other being at all affected, and in the process of dying, we shall find all the sensorial functions finally lost, while all the nervous functions remain, and are only indirectly impaired by the loss of the former.

The sensorial functions constitute the sensitive system,—that by which we perceive and act,—and consequently are connected with the world which surrounds us. The nervous and muscular, the vital system, that by which we are maintained.

From the same experiments it appears, that what is called death consists in the loss of the first of these classes of functions, the sensorial, the nervous and muscular functions still continuing, which are lost only in consequence of the failure of respiration, the only vital function to which the cooperation of the sensorial power is necessary.

Many hypotheses have been framed for the purpose of explaining why the motions of the heart and blood-vessels are not, like those of the limbs, subjected to the will. Among these is the hypothesis of Dr. JOHNSTONE of Worcester †, adopted from WINSLOW, PROCHASKA, and other writers, which professes to rest on the evidence of experiment, and ascribes to the ganglions the power of intercepting the influence of the brain, and consequently of the will. We have seen, however, that the influence of both the brain and spinal marrow reaches the heart and blood-vessels as readily as the muscles of voluntary motion ‡.

All that has been written on this question seems only to perplex it. When we dismiss the various hypotheses on the subject, the answer appears easy. There are evidently two conditions necessary to render a muscle subject to the will: the stimulus which excites it must be so, and it must be capable of effecting an end desired. If we had no wish to handle, the muscles of the hand would never have become subject to the will. The heart and blood-vessels in all their usual motions are excited by the blood, the stimulating properties of which the will can neither increase nor impair; and what act of volition could be performed by these organs? The only internal organs which can effect an end desired, are the rectum and bladder, when their contents have accumulated to a certain extent; and they are both, under such circumstances, subjected to the will. Their action here may be said to be vital functions, to which the cooperation of the sensorial power is necessary; but, to say nothing of the sensorial

* Philosophical Transactions for 1815, 1829, and 1833; and my Experimental Inquiry into the Laws of the Vital Functions, Part II. chap. ii. Third Edition: wherever this Inquiry is referred to, the references are to the Third Edition.

† Essay on the Use of the Ganglions; published in 1771.

‡ Philosophical Transactions for 1815; and Experimental Inquiry, Part II. chap. i. and ii.

power under all circumstances not being essential to them, they are not so immediately essential to life as to be comprehended in the term vital functions, according to its usual acceptation.

When the animal no longer feels and wills, his breathing ceases and he is, according to the common acceptation of the term, dead, although his body still retains its other powers, which, while they last, prevent its obeying the laws of inanimate nature*; but the changes which after this take place, of course no more affect the individual than if they took place in any other mass of matter.

In inquiring into the physiological nature of what is called death, therefore, it is to the ceasing of the sensorial functions alone that the attention must be directed. Thus the subject divides itself into two parts; the final loss of the sensorial functions, which in common language has obtained the name of Death; and absolute death, that is, the loss of all the functions, which we shall find in the more perfect animals is the necessary consequence of the loss of the sensorial functions.

The latter functions, as I have already had occasion to point out in my paper on the Nature of Sleep, published in the first part of the Philosophical Transactions for 1833, belong to those parts of the brain and spinal marrow which are associated with the nerves of the sensitive system, and which, it appears, from another paper which the Society did me the honour to publish in the same part of the Transactions, are the only active parts of the sensorial system; those on which the power of all its other parts depends. To them, therefore, we must look for the immediate cause of failure when the functions of the sensitive system, whether temporarily or finally, fail. It is here we found that the immediate cause of sleep exists; and it appears, from what has just been said, that to the same parts we must look for the immediate cause of what is called death.

The state which immediately precedes the last act of dying, then, according to the common acceptation of the term, and sleep, depend on a failure of function in the same organs. In what, then, consists the difference of these states? The most evident is, that the one is a temporary, the other a final failure; and it will appear, that in the only death which can strictly be called natural, the state of the sensitive system which immediately precedes death differs from its state in sleep in no respect but in degree.

The cause of sleep, as appears from the paper above referred to, is uniformly the same,—a diminished excitability of the sensitive parts of the brain and spinal marrow, in consequence of the action of the ordinary stimulants of life; but a loss of excitability in those parts we shall find is never the sole cause of death, and often makes no part of its cause. In sleep we have seen that the sensitive parts of the brain and spinal marrow regain their functions in consequence of the continued vigour of the vital system, by which their excitability is restored. To render the exhaustion which constitutes sleep permanent, therefore, the powers of this system also must fail;

* Experimental Inquiry, Part II. chap. xi.

and if any cause of failure in these powers occur, it is evident, that whatever be the state of the sensitive system, its powers must fail with them.

THE natural death of the animal is the death of old age; and as this is the simplest form of death, it is that which I shall first consider. We shall find that the state which immediately precedes this death, and must consequently be considered as its cause, must, in the nature of things, differ from sleep in no other respect than the less vigorous state of the functions of both systems, and consequently that these states are identical; the greater or less general vigour making no difference in their nature.

We are not necessarily born to suffering. All natural states, with the exception of child-bearing, (and in its most natural state even this is hardly an exception,) are more or less pleasurable. It will appear from the nature of our constitutions, that the last feelings in natural death are necessarily of the same nature as those which precede sleep. It is only where the course of our decay is disturbed, that suffering of any kind attends it.

From a knowledge of the animal economy, we might, independently of experience, have foretold that a state of sleep would be that which immediately precedes the last act of dying from old age. It appears from what was said of the nature of sleep in the paper above referred to, that although the vital organs do not, in it, partake of the peculiar state which constitutes sleep, their functions are all, for the time, impaired by the exhaustion of the sensitive system. The respiration, we have seen, is rendered less frequent, in consequence of which the activity both of the circulation and the other assimilating functions which depend on it, is, for the time, lessened.

Now, as the death of old age arises from the gradual failure of those functions, it must necessarily take place at the time at which their vigour is most impaired. If the vital powers are still capable of restoring the sensitive system under the disadvantage of a diminished frequency of respiration, it is evident that, if their decay be gradual, nothing occurring suddenly to accelerate it, they cannot fail to maintain the functions of that system during the short time which intervenes before the recurrence of sleep again exposes them to the same difficulty. Their failure necessarily takes place at the time when their functions are most difficult. The death of old age, therefore, is literally the last sleep, uncharacterized by any peculiarity. The general languor of the functions in the last waking interval is attended with no peculiar suffering, and the last sleep commences with the usual grateful feelings of repose, the last feelings experienced; for with what takes place after them, the feelings, being suspended, have no concern.

The only difference between the last, and the sleep of former times, is, that the exhaustion of the sensitive system, which is at first, as in the latter case, only partial, (for in the beginning of this sleep the sleeper may be roused by more powerful stimulants than those which preceded it,) becomes in its continuance, in consequence of the failure of those powers which formerly restored the sensitive system, complete.

As it is by the continued action of the vital parts in sleep that the sensitive parts are restored, the less active the former become, they necessarily effect their restoration the less readily; and when they can no longer effect it, the individual awakes no more; but the circumstance of the vital being no longer capable of restoring the sensitive system, makes no alteration in the nature of its exhaustion. It is still, while it lasts, the same exhaustion which constitutes sleep. The sleep proves final; but the sleeper is wholly unconscious of the cause which renders it so; and there is nothing in its commencement to inform us whether it will be final or not. Thus the sensibility is extinguished, and consequently respiration ceases. The extinction of the sensibility is the last act of dying, in the common acceptation of the term. As the ordinary stimulants of the day produce the sleep of daily occurrence, those of life produce the sleep of death.

Although the sleep of each day restores the sensitive system from the exhaustion which causes it, the daily recurrence of the exhaustion has the effect of permanently lessening the excitability of that system; a change not to be perceived from day to day, but which, from many phenomena, becomes sensible in the course of years. As the sensitive system becomes less excitable as the day advances than on first awaking, so it becomes less excitable as life advances than in childhood; and in like manner, as the repeated excitement of the sensitive system tends to the final decay of its sensibility, the continued excitement of the vital system, as we might *à priori* have supposed, has a similar tendency with respect to the excitability of this system. We find the pulse becoming slower as we advance in life, in consequence of the lessened excitability of the heart and blood-vessels, and the vital organs less readily influenced by the parts of the nervous system associated with them, proving that their functions also are under the process of decay. On the functions of these parts and the powers of circulation, all the assimilating processes depend; and the shrinking frames of the aged indicate their weakened state and the approach of their final extinction; for those were deceived who taught that there is nothing in the laws of our frame which should lead us to believe that it is not formed to last for ever.

The greatest degree of excitability, either in the sensitive or vital system, is not that which produces the most vigorous state of health. We may be too excitable as well as too little so. Many of the more serious diseases of children arise from this cause. The derangement of the digestive organs, which in the adult produces the nervous irritations of indigestion, produces in the infant inflammation of, and effusion on, the brain. The irritation of the gums, which produces pain and restlessness in the former, in the latter produces convulsions and death. Thus it is that the habit of the child is less firm and vigorous than that of the adult, which has acquired steadiness by the diminution of its excitability, in consequence of the continued action of the stimulants of life; but, after a certain period, the fault is a deficiency, not a redundance, of excitability, a defect apparently the necessary consequence of the laws of our frame, and to which every day unavoidably adds.

The redundance of excitability in children, the cause of many evils, we may be assured answers some important end. There is reason to believe that it is on it that the growth of the body depends, and that the due proportion between the excitability and the stimulants of life, by the gradual diminution of the former, determines the period at which the growth is completed in each individual. While the excitability continues redundant, the ordinary stimulants of life necessarily support a greater activity of the functions than is required for the mere maintenance of the body, and thus its volume enlarges, on the same principle that we have just seen it shrinks in the aged, in consequence of their excitability having become defective. It seems to be on this principle, namely, by a premature exhaustion of the excitability, that the hardships of life, that is, the greater than usual application of its stimulants, check the growth. On the same principle we should expect to find that the growth would cease soonest in the most excitable habits, because in them the excitability will soonest be reduced to a due balance with the stimulants of life. Thus it seems to be that the growth of women, who are more excitable than men, generally stops sooner, and consequently that they are of shorter stature, large women, for the most part, having less of the habit peculiar to their sex; and that by far the greater number of the most excitable men, who, in consequence of this constitution, make the greatest figure in their day, are men of short stature, while giants are generally of an opposite habit of body. There must, of course, to such rules be many exceptions. Where so many causes are operating, no result can be uniform.

THE form of death above described is the only one which, strictly speaking, can be regarded as natural. In all its other forms the regular course is disturbed by adventitious causes. But the causes which interfere with the regular course of nature, and which make their impression either directly on our bodies, or through the medium of our mental powers, are, in civilized society, so numerous and complicated, that it is rare to see an instance of such a death. At whatever period death arrives, it is almost always the effect of disease; and at advanced periods of life we only become more liable to death in consequence of our weakened powers rendering us more subject to disease.

Of the various instances of death I have witnessed, there was none that could be regarded as wholly the effect of age. It was always possible to point out some one or more of the vital organs more deranged than the rest, to which death was chiefly to be ascribed. We have, however, accounts of death from old age alone, which were such as has just been described, so that the inferences afforded by the laws of the animal economy are here confirmed by experience.

If we wish to prolong life, we must keep the attention so far directed to the health as to watch the first tendency to failure in any of the vital functions. In a great majority of instances, to a very late period of life, the failure in the commencement is capable of being corrected. By continuance it becomes obstinate, and by the laws

of sympathy spreads to other parts. We may be assured there is, in all, the capability of long life if they can escape the effects of disease. Thus it is that those who lead a quiet and retired life, little exposed to powerful impressions either of mind or body, often attain a great age. It is an additional motive for watching the state of health at advanced periods of life, that the longer we live the less in general is our suffering at the last; the nature of our death partaking the more of that of old age. For the further consideration of this subject I beg to refer to my Treatise *On the Preservation of Health, and particularly the Prevention of Organic Diseases.*

ALL modes of death, with the exception of that from old age, may be regarded as more or less violent; but in considering their nature, we must not confound the last act of dying with the suffering which precedes it, and which is often no less when it terminates in recovery than in death, which equally relieves it; and as death, in the usual acceptation of the word, from whatever cause it arises, consists in the loss of the sensorial functions alone, the act of dying is, in this respect, in all cases essentially the same. In all my experiments I found the nervous and muscular surviving the sensorial functions*.

When the animal no longer feels and wills, he is what we call dead; but for a certain time the motion of the blood in every part of the system still continues, and all the assimilating functions still go on, as may be demonstrated by dividing the vital nerves immediately after death, which produces the same change of structure in the organs supplied by them, though in a less degree, as during the life of the animal†; and that all this would be the case, a knowledge of the animal economy would have told us, independently of the aid of experiment, if we could, without this aid, have acquired it.

The removal of the sensorial powers neither destroys the muscular power nor deprives the muscles of involuntary motion of the stimulus which excites them. The heart, indeed, is incapable of its function, because, from the interruption of respiration, its left side is no longer supplied with the kind of blood which is its natural stimulant; and the accumulation of the blood in the lungs from the same cause affecting a great proportion of its vessels, prevents the right side from emptying itself. These are the necessary and almost immediate effects of the interruption of respiration; but the change in the blood of all the capillaries, with the exception of those which belong to this class of vessels, necessarily takes place more slowly. A certain time must always elapse before the stoppage of respiration greatly affects it. It has been sent to these vessels more or less in its proper state, and it still finds its vessels capable of being influenced by their usual stimulant‡. Thus, as I have ascertained

* Experimental Inquiry, Part II. chap. xi.

† Ibid. pp. 175, 176, compared with a paper which the Society did me the honour to publish in the Philosophical Transactions for 1827, entitled, *Some Observations on the Effects of dividing the Nerves of the Lungs, &c.*

‡ Philosophical Transactions for 1833.

by many experiments, the motion of the blood continues in these vessels for several hours after respiration has ceased, that is, as long as the blood can be drawn from the larger arteries,—the cause of these arteries being found empty some time after death*.

But this is not all; the nerves of the ganglionic, as well as cerebral system, retain their power for a certain time after the supply of that power from the brain and spinal marrow has ceased†. The blood therefore still finds the secreting surfaces in a state more or less capable of their functions, and the secreting processes, as I ascertained by frequently repeated experiments, still go on‡: nor is even this all, for the brain and spinal marrow depend for the continuance of their functions on the same powers as other organs; and I found, by an experiment made on so large a scale that it was impossible to be deceived in the result, that there is an actual supply of nervous influence after the sensorial functions have ceased, that is, after what is called death§.

SUCH is the natural decay of our frames; but, as I have already had occasion to observe, it is very rare for it to run its course uninterruptedly, particularly in civilized life. It is almost always disturbed by adventitious causes accelerating it, or the decay of particular parts, which, in consequence of the mutual dependence of the various functions, disorders the whole. Although these causes are of infinite variety, the laws of our frame are limited, and therefore many must operate on the same principle. This leads us to believe that, however varied the causes of disease, it may be possible to reduce their more ultimate effects to a few general heads. The exhaustion of the sensitive system, for example, is of the same nature, whatever be the cause of excitement; and other forms of debility, affecting either the sensitive or vital system, cannot be very various, however various the causes which produce them. We have reason to believe that the endless variety of disease depends more on the peculiar nature and functions of the different organs affected, and the peculiar manner in which different causes affect them, than on any great variety in the states which constitute the more immediate causes of death. However various the effects of disease, there must be but a few points to which they all tend, because the last in the chain of causes which produces what is called death, we shall find, is always the same, and seated in the same parts. On these principles we may hope to reduce the effects of the adventitious causes of death to a few heads, and thus to obtain such a view of the subject as shall enable us to trace the nature, and consequently the operation, of the causes of our decay in individual instances, and therefore to perceive more clearly the operation of the means which tend to counteract them. In the prosecution of the

* Experimental Inquiry, Part II. Experiments 66 and 67.

† See the Observations on the Experiments, which prove the evolution of caloric from the blood after what is called death, in the second part of the Inquiry just referred to.

‡ Ibid. Experiments 65, 69, 70.

§ Experimental Inquiry, Part II. Experiment 65.

subject I shall commence with those causes of disease whose operation most resembles that of the wholesome stimulants of life; and in pursuing, by means of the various experiments which tend to unfold the laws of the animal economy, the consequences of these causes, we shall be led to the effects of such as have nothing in common with them.

IT appears, from what was said of the nature of sleep, that all degrees of excitement in the parts of the brain and spinal marrow associated with the nerves of the sensitive system, are followed by proportional exhaustion. The only limit to this law is the capability of bearing in those parts. Exhausted by mental excitement, the criminal is often awakened for his execution; and the soldier, both by mental and bodily excitement, sleeps by the roaring cannon.

Now although the usual stimulants of the day never, except in old age, where we have seen all our powers have long been in a state of decay, produce such exhaustion as to endanger life, the exhaustion from stimulants of greater power cannot with safety be frequently repeated, because by their continued operation the sensitive parts of the brain and spinal marrow being both more exhausted than is consistent with the due state of the functions before sleep takes place, and roused before they have been refreshed to the usual degree by repose, a state of disease is induced; and all diseased states affecting the system generally, if their causes continue to operate, necessarily prove fatal.

Although in ordinary sleep the vital functions are for the time impaired in consequence of the lessened sensibility rendering the act of respiration less frequent, the state both of the vital and sensitive system is as much a state of health as in our waking hours. The insensibility of the latter only extends to the effects of the daily stimulants of life; and there are ample means in the functions of health for the restoration of this system, the powers of the vital system, as I have already had occasion to observe, being in no degree diminished, but only, in consequence of a slower respiration, less readily excited.

As soon as a diseased state of the sensitive system is established from the causes just mentioned, it begins to affect the vital system otherwise than through the intervention of respiration, the only medium, we have seen, through which the healthy exhaustion of the former affects the latter; for such is the sympathy between the sensitive and vital parts of the brain and spinal marrow, that any deviation from the healthy state of either is immediately felt by the other.

The characteristic of the mode of death I am considering, is the tendency of its causes to produce sleep in the first instance. So far their operation is the same, but greater in degree, with the common stimulants of life. At this period, if the cause of suffering be removed, the sleep is only more profound than on former occasions; and, as on them, it continues till the sensitive system again becomes obedient to those stimulants; if not, this system soon partakes of a species of debility so dif-

ferent from the healthy exhaustion, that instead of being relieved by the continued action of the vital parts of the brain and spinal marrow, it spreads to them. Hence the nutritive and other vital processes begin to fail*, and the various irritations which attend their failure, still further contribute to the debility of the sensitive system, and consequently, indirectly, to increase the cause of their failure. The derangement of each system thus aggravating that of the other, the evil proceeds not by simple addition, but in an increasing ratio, till all their powers are extinguished.

WHATEVER be the suffering which precedes what is called death, the moment of that death is but its termination, but the conclusion, as far as our feelings are concerned, of the process of dying. As soon as disease is established the act of dying is begun, and we have no reason to believe that, as far as the body is concerned, its nature is in any respect changed in what is called its termination. It is, from the first to the final ceasing of all the functions, a more rapid than natural decay of the powers of life, with, while sensibility lasts, more or less suffering, according to the cause which produces it. In recovery, our suffering terminates by the removal of that cause; in what is called death, by our becoming insensible to its effects; the bodily process being in no other way influenced by our total insensibility, to which the name of death is applied, but that the consequent ceasing of respiration accelerates it.

The body at this moment can no more be regarded as in the act of dying than at any other period of the disease; and the removal of the offending cause will not only in many cases at this period, if proper means be employed, but in some, even a short time after it, be followed by recovery. Thus, even after the period at which, according to the common meaning of the word, the process of dying is completed, it is, under certain circumstances, not too late to arrest that process, and restore the sufferer to the perfect enjoyment of his faculties. Recovery may take place after respiration has, from submersion, for a few minutes ceased, and the sufferer is, in the common acceptation of the term, dead, his sensibility, and consequently his respiration, independently of artificial means, being finally extinguished.

That this may happen, it is necessary not only that the vital system should have been just before in a state of healthful vigour, but also that the respiration should not have failed from the failing sensibility, but the operation of the offending cause. Here the sensibility fails from the failure of respiration, not, as in other cases, the respiration from the failure of the sensibility; but this difference in the succession of events makes no difference in the general nature of the actual state induced.

The recovery depends on our being able, more or less perfectly, to restore the function, the failure of which has caused the failure of all the others, as far as it has taken

* That the assimilating processes depend on the action of the nervous influence on the blood, appears from various experiments, an account of which has been laid before the Society. Many of these experiments are detailed at greater length, and others, illustrating the same position, added in my Inquiry into the Laws of the Vital Functions, Part II. chap. v., vii. and viii.

place, before the process of dying has proceeded too far for the restoration of the sensitive system. If no artificial means are employed, the date of death here is the time at which the sensibility ceased, and justly, because at that time death, according to the common meaning of the word, has taken place. The individual no longer feels and wills.

If there were even the last remains of sensibility, breathing would take place without external aid, as happens when the submersion has not been long enough wholly to extinguish it. The individual has, without such aid, finally ceased to feel and will, and is therefore what we call dead. His blood still continues to move, and all the assimilating processes, as appears from the experiments above referred to, are still going on; but this is no more than happens, more or less, in all cases after what is called death; the only difference being that from the nature of the offending cause, and the short duration of the disease, these functions are in a state of greater vigour than when the loss of respiration has been the effect of the loss of sensibility, which makes no difference in the nature either of their remaining powers or the circumstances in which they are placed, and would not prevent their ceasing, as usual, if no means were employed to arrest the dying process. I have dwelt the longer on this case, because it affords a good illustration of some of the preceding as well as following parts of the subject*.

THE approach of death, if we are aware of it, must always be more or less impressive, not only because we are about to undergo an unknown change, but are leaving all

* From the experiments which have been laid before the Society (Philosophical Transactions for 1822, 1827, and 1829, and Experimental Inquiry, Part II. chap. xii.), we have reason to believe that the effects of artificial respiration in restoring those whose breathing has been interrupted till the sensibility is destroyed, would be greatly aided by the use of voltaic electricity sent through the lungs in the direction of their nerves, and that many might thus be restored in whom inflation of the lungs alone fails. The inflation of the lungs in such cases acts in two ways. It gives to the blood of the smaller vessels of the lungs some of the arterial properties by which they are often excited, and acting through the blood of these vessels, it communicates to that of the larger vessels, and of the heart itself, more or less of the same properties, independently of the blood already changed being moved on towards this organ; for M. LE GALLOIS has shown that after the circulation has permanently ceased, the blood may, to a certain degree, be changed by inflating the lungs, not only in the trunks of the pulmonary veins and the heart itself, but even in the great arteries.

There is reason to believe, from the whole of my experiments, that the lungs should not be inflated more than eight or ten times in the minute, and that the injection of large quantities of air and great force in its injection should be avoided, and consequently the patient placed in the position in which the chest expands with greatest ease†. One of the chief defects of artificial breathing is, that in it the chest is expanded by

† Experiments relating to the effects of artificial respiration in the newly dead animal: Experimental Inquiry, Part II. chap. xii. If the air be thrown in more frequently or in greater quantity than the remaining powers of the lungs are capable of employing, it acts as a cooling process and is highly injurious. It is one of the defects of artificial respiration that we cannot tell either the precise quantity of air or the frequency of its injection required by the particular state of the circulating system in the lungs. We know that in the case before us, the demand cannot be equal to what it is in health.

that has hitherto interested and been grateful to us. Even here, however, for the most part, the laws of our nature are merciful. Most diseases of continuance, (for we shall find there are some exceptions,) not only gradually impair our sensibility, but alter our tastes. They not only render us less sensible to all impressions, but less capable of enjoying as far as we are still sensible to them. The sight of a feast to a man who has lost his appetite is disgustful, and a similar change takes place in a greater or less degree with respect to all other means of enjoyment.

These circumstances constitute a great part of the difference of our feelings with respect to what, in common language, is called a violent and a natural death. In the latter, as far as the sensibility is impaired, we are more or less in the state of old age, and, in addition to this change, our tastes are perverted. By these means the relish for life is in a great degree destroyed before we lose it. Thus in disease, the most timid often meet death with composure, and sometimes, as I have repeatedly witnessed, with pleasure. I have even known the information that the danger was passed, received only with expressions of regret.

To the form of death I am considering, belong a large proportion of the diseases of long standing, and whatever else tends gradually to exhaust the powers of the sensitive system, great mental excitement, too laborious a life, &c. The diseased state of the sensitive parts of the brain and spinal marrow, thus induced, spreading to the vital parts of those organs, terminates in a state of nervous apoplexy, the nature of which I had occasion to explain in the paper on Sleep above referred to, and to contrast with that of apoplexy from compression, in the most unmixed cases of which, the offending cause

the pressure of the injected air, whereas in natural breathing the air enters in consequence of its expansion. But the most essential difference between natural and artificial breathing in such circumstances is, that there cannot, till recovery is far advanced, be the proper supply of nervous influence, the due action of the vital parts of the brain and spinal marrow only being restored in proportion as the due force of circulation returns. Now it appears from what is said in the Philosophical Transactions for 1822 and 1827, and more fully in my Inquiry into the Laws of the Vital Functions, that voltaic electricity sent through the lungs in the direction of their nerves, is capable of performing as perfectly as that influence itself, the part which belongs to it in respiration, which is so essential, that the more perfect animal always dies from impeded respiration if the nervous influence be withdrawn from the lungs, unless voltaic electricity be supplied, which enables it to breathe as well as when the nervous influence is entire.

A proper apparatus, therefore, for sending voltaic electricity through the lungs in the direction of their nerves and in due power, should be added to the other means of resuscitation, which would render them, and probably to a great degree, more successful. The force of this observation will be perceived when it is considered that it is at the time of the first application of the remedies that the chance of recovery is greatest, and consequently that the immediate application of the whole means of healthy respiration, as far as we possess them, is of most consequence. It appears from what has been said, that the due functions of respiration cannot be restored till the due degree of nervous influence is supplied, and this cannot happen from inflation of the lungs till the due force of circulation returns. Now the fact, explain it as we may, is, that voltaic electricity so perfectly supplies the place of the nervous influence in the lungs, that their functions are equally perfect under the influence of either. The one can only be supplied at an advanced period of recovery, that is, in fact, only in those cases where the success of our endeavours can be secured by other means; the other is, in all cases, within our reach on the instant.

only producing a state analogous to the healthy exhaustion of the sensitive system but greater in degree, its influence is throughout confined to that system*. In the former case we see all the vital functions deranged; in the latter, the breathing alone affected, except as far as its state affects the others, death arising merely from respiration ceasing in consequence of the loss of sensibility; and so exclusively is this sometimes the case, that I had occasion to refer to an instance in which the patient breathed only two or three times in the last ten minutes, but each time drew the air freely into the lungs; a proof that he died without any accumulation of phlegm there, and consequently without any disorder of the vital functions, but such as arose from the increasing insensibility†. Here the failing powers of the sensitive affected the vital system in no other way than in sleep, the only difference being the degree in which the sensibility was impaired. Such cases are extremely rare. In by far the majority, from some inequality in the effects, or other peculiarity of the cause of pressure, at the same time that the sensibility is morbidly impaired, either a diseased state of a different kind is induced on the sensitive parts of the brain, which, as soon as established, begins to spread to the vital parts of that organ, or the cause of the disease itself more immediately affects the latter.

In the more rapid cases, the diseased state of the sensitive, which spreads to the vital parts of the brain and spinal marrow, supervenes without being preceded by a state of exhaustion, only differing from sleep in being greater in degree, in proportion as the stimulants which produce it are more powerful and protracted.

The effects of diseased states of the sensitive on the vital parts of the brain and spinal marrow, differ according to the nature and degree of the offending cause. When they are such as in the first instance to produce a state analogous to sleep, their injurious effects are necessarily more or less gradual, the first operation of the agent differing only in degree from that of the usual stimulants of life; but where the offending cause is more powerful in degree, or of a more injurious nature, the stage of exhaustion is lost, and the immediate effect on the sensitive system is that species of debility which the vital parts of the brain and spinal marrow having no power to relieve, partake

* It appears from experiments related in my Inquiry into the Laws of the Vital Functions, that simple and uniform pressure of the brain does not produce such a state of the vital parts of that organ as to derange the circulation, the effect of such pressure on the sensitive organs of the brain being of the same nature, as far as relates to the vital system, as the exhaustion occasioned by the exercise of their functions; which further appears from the whole functions of health being immediately restored on the removal of the pressure, which only proves fatal by its continuance more and more impairing, and at length destroying, the sensibility. (Experimental Inquiry, Part II. Experiment 18.) Many years ago, a man in whom the ossification of the skull had never been completed, exhibited himself in this country. By pressure made on the unossified part he was immediately brought into a state of apoplexy, which always disappeared, leaving him wholly uninjured, on the removal of the pressure.

† It has been shown by many experiments, detailed in the Philosophical Transactions, and in the second part of my Inquiry into the Laws of the Vital Functions, that derangement of the assimilating functions is always attended with accumulation of phlegm in the lungs, this being the first indication of derangement of these functions in them.

of; and when the cause is both violent and sudden, its effects on these parts are often such as immediately to destroy the circulation.

The Experiments, an account of which the Society did me the honour to publish in two papers in the Philosophical Transactions for 1815, prove that, although the heart and vessels do not derive their power from the brain and spinal marrow, it may be destroyed by impressions made on them. Thus it is that violent passions, either of a pleasurable or painful nature, in consequence of the sympathy which subsists between the sensitive and vital parts of these organs, have sometimes proved instantly fatal.

Here we have an effect from the causes of disease wholly different from that of the usual stimulants of life. The direct operation of the agent produces a state of debility in the sensitive system altogether of a different nature from that which constitutes the healthy exhaustion of sleep; and it will assist the memory and facilitate the means of reference to regard as the second form of what, for the sake of distinction, I call violent death, that which arises from all those causes which produce in the sensitive system this species of debility in the first instance, that is, debility without previous excitement, in whatever degree they have this effect; regarding, as the first species of such a death, the form of death we have been considering, that in which the cause, in the first instance, produces the stimulant effect, and consequently the exhaustion of sleep.

WHEN the cause of the second form of violent death, according to this division of the subject, is extreme, no time is afforded for its less powerful effects to show themselves. When it is less violent, so that the circulation, though impaired, still goes on, we find all the vital functions impaired along with it. The assimilating processes are doubly assailed by the failing supply of nervous influence and the lessened powers of circulation*. These effects, we have seen, may arise from the excess of the stimulant operation of agents†, but they are not necessarily the consequence of any operation of this kind, but may be as much the direct effect of the agent as the stimulant effect itself. It is, the offending cause and state of body being the same, when the operation of that cause is most powerful, that its debilitating effect is most unmixed. In proportion as it is less powerful, the case partakes more of the nature of the form of death, in which the first effect of the offending cause is that of a stimulant.

This is readily explained. I have been at much pains, in my Inquiry into the Laws of the Vital Functions, to point out that all agents capable of affecting the living animal, whether making their first impression on the mind or body, applied in a certain degree, act as stimulants, in a greater degree, as sedatives; that is, as means of directly impairing the power of the part they act upon ‡. We know of no exception

* See note in p. 177.

† See pp. 176 and 177.

‡ Experimental Inquiry, Part II., the last ten pages of chap. xi.; and the observations on the term sedative in my Treatise on the Influence of minute Doses of Mercury, which, from the want of some more appropriate term, I shall here employ for all agents which impair the power of the whole or any part of the animal frame without producing previous excitement.

to this law, and the stimulant and sedative effect of different agents bear no particular proportion to each other; but the greater the stimulant power of the agent, it must be applied to the greater extent to produce the sedative effect, and the greater its sedative power, in the smaller extent, to obtain from it the stimulant effect. The proportion which the stimulant and sedative effects of the same agent bear to each other is always the same, that is, its mode of application and the state of the body being the same; for the more gradual the application, the more the stimulant; the more sudden, the more the sedative effect prevails; and the less vigorous the functions, the less they are capable of the stimulant, and the more they are subject to the sedative effect. Thus torture, which, in the hardy savage, produces sleep, that is, the exhaustion which is the effect of the stimulant operation, acts as a sedative in the less robust European. While the former sleeps, the latter dies; and the more sudden its application the less the constitution is capable of resisting it.

The sedative effect, in whatever degree, is of a nature so different from the exhaustion which constitutes sleep, that its tendency always is to prevent the latter; and when the stimulant operation of the causes of disease exceeds that of the usual stimulants of life, and thus tends to the sedative effect, in the same proportion the tendency of these causes, although in the first instance to produce sleep proportioned to their stimulant effect, is eventually to prevent it. The repetition of fatigue at length produces fever, not sleep.

Such being the principles on which all agents capable of affecting the living animal operate, we readily perceive why the more sudden and powerful the cause of disease, the more it inclines directly to produce a state of debility, and when it is most so, why this tendency is unmixed with any degree of the stimulant effect.

But it is not necessary, as appears from what is said of nervous apoplexy in the preceding paper, that the operation of the agent should be either violent or sudden, to produce, even in the first instance, more or less of the sedative effect, if it be of a nature suited to produce it. In proportion as its application is less powerful, however, its peculiar effects are necessarily so also. Instead of preventing the tendency to sleep, it only impairs it; and the morbid state of the brain and spinal marrow shows itself by symptoms which less immediately threaten life. The sedative effect of agents may exist in all possible degrees, from the effect of the rage and joy which has produced instant death, to that of the settled grief, which only in the course of years destroys its victim; from the pain of a scald so extensive as to produce death in a few minutes, to the irritations of confirmed indigestion, under which the patient often lingers for a great portion of life. Whether the effects be sudden or gradual, the tendency, in all such cases, is the same, to terminate in a state of general debility, that is, nervous apoplexy, in which all the powers of the system are equally impaired.

The first impression of the cause is on the sensitive parts of our frame, which, without previous excitement proportioned to the debility which ensues, impairs their

functions; and this debility, in consequence of the sympathy which exists between the sensitive and vital parts of the brain and spinal marrow, spreads to the latter, and thus the vital functions are, more or less quickly, so impaired that they can no longer maintain those of the sensitive system.

The nature of this death is well illustrated by the effects of severe accidents, many of which operate on the same principle as the scald. The effects of severe blows on the head and spine are very complicated. They at once impress equally the sensitive and vital systems; but when the cause of injury is confined to less vital parts, as in the case of the scald, its first impression is on the sensitive system alone, or so nearly so, that the difference may be overlooked. Such was the cause of death in the case of the late Mr. Huskisson, with the circumstances of which the members of the Society are well acquainted; and hence it is that life is often saved by amputating a limb in which a cause of extreme irritation exists, that caused by the operation being more easily borne than the protracted irritation of a shattered limb, if the accident has not so subdued the strength that the additional irritation of the operation would prove immediately fatal.

To the same head belongs the death from the bite of rabid animals. The hydrophobia is a disease of the sensitive, spreading to the vital, parts of the brain and spinal marrow; and such is the effect of many other poisons.

It is evident that the form of death I am now considering is of the same nature as the preceding, with the exception of the early stage of the latter. The sedative state produced in the sensitive organs is of the same nature, whether it has arisen from the excess of the stimulant operation, or from the more direct effect of the agent, when applied in such extent as at once to produce this state. The symptoms produced in the sensitive, and the manner in which they influence the vital, system are the same in both. The same observations, therefore, which apply to the latter stage of the first of these forms, apply, more or less, to the whole progress of that we are considering. In both, what is called death is the final extinction of the sensibility; the termination, as far as relates to our consciousness, of the process which has been going on from the first establishment of the disease. As sleep is the completion of the temporary and limited exhaustion of the excitability which has been going on during the day, death is here the completion of its absolute and final exhaustion, which has been going on during the disease; and it is evident, that as the sensibility decreases, the suffering must become less, and consequently that it is least of all at the moment of what is called death. These observations, however, we shall find do not apply, in the same extent, to the forms of death which still remain to be considered.

THE three forms of death to which the attention has been directed in the preceding part of this paper, namely, that from old age, that from excessive stimulants acting on the sensitive parts of the brain and spinal marrow, and that from agents applied to such extent as to act as sedatives on those parts, agree in an essential respect.

The offending cause makes its impression on the organs of the sensitive system, and therefore in all, the sensibility is more or less directly impaired by it; and although it is only in the first that sleep can be regarded as the immediate cause of what is called death, the cause of injury in the second stage of the second form, and throughout the whole of the third form, producing the sedative effect, and consequently more or less tending to prevent sleep, yet tends, although in a different way, to impair the sensibility; and the termination in all such cases, as I have already had occasion to observe, if no other cause of injury arise in the course of the disease, is a state of nervous apoplexy, in so many cases the prelude of death, which, if not sufficiently violent or sudden, so to impair the powers of circulation as thus immediately to destroy those of the sensitive system, proves fatal by equally impairing the sensibility and impeding the assimilating processes; and as sleep relieves us from the ordinary stimulants of the day, the insensibility thus induced, relieves us from the sufferings of the disease, which, although it is not, like sleep, preceded by the grateful feelings of repose, is preceded by a gradual diminution of those sufferings.

THE forms of death which remain to be considered differ essentially from the foregoing. It will place in a clearer point of view both what I am about to say of these forms of it, and what has been said of its preceding forms, to consider more minutely than has hitherto been done in this paper, or, as far as I know, in any other discussion on the subject, the nature and relation of the functions of the living animal.

IN the community of functions which constitutes the life of man and all the more perfect animals, the sensitive are the working functions, those by which we perceive and act; the vital, those by which they are maintained. To the former, therefore, belong the immediate wear and tear of intercourse with the external world, and, consequently, the necessity of accommodating themselves to an infinite variety of circumstances. The vital functions, having but one object, pursue a steady course, from which, in health, they never deviate, except as far as is necessary to accommodate themselves to the necessities of the more eccentric functions of the sensitive system, the well-being of the organs of which depends on them; for they are capable of immediately influencing as well as being influenced by the inanimate agents which exist within our bodies; on the action of which the due structure as well as functions of every part depend. On this principle our food is digested; on the same principle the heart beats, and the secreting and other assimilating organs effect all their chemical changes. Thus the sensitive parts of the brain and spinal marrow are maintained, and thus also are maintained two sets of organs; through one of which, namely, the organs of the external senses with the nerves which convey the impressions made on them, these parts are capable of being influenced by the inanimate agents external to our bodies; and through the other of which, namely, the nerves and muscles of voluntary motion, they are capable of influencing those agents. These two sets of organs, allied by their

vital properties to the sensitive parts of the brain and spinal marrow, and by their capability of being excited by inanimate agents to the world which surrounds us, form the links which connect and enable to conduce to one end the operations of the sensitive organs, namely, the immediate organs of the sensorial powers, and the operations of inanimate nature; two classes of operations which have nothing in common. Let us here pause to consider more particularly the positions stated in this paragraph.

However repugnant it may be to our preconceived opinions, we shall, I think, when the whole of the facts on the subject are carefully weighed, find it impossible to avoid the conclusion, that all the vital functions, and all those functions of the sensitive system by which the sensorial powers influence and are influenced by the external world, are the results of inanimate agents acting on living parts, or living parts on them. Such, as far as I am capable of judging, must be the conclusion, if we compare the results of experiments, an account of which has been laid before the Society, and published in their Transactions *, with observations too simple to require any illustration from experiment.

With regard to the first of these classes, the vital functions, it is evident that the functions of the alimentary canal are excited by the food, of the lungs by the air, and of the heart and blood-vessels by the stimulating contents of the blood.

The blood, as it circulates in the vessels, is justly said to be alive. It possesses properties essentially different from those of inanimate matter; but we know that it is not by its vital properties, which are bestowed on it for other purposes, that it stimulates the heart and vessels, because its stimulating contents, when separated from it, produce the same effects on them. The experiments relating to the evolution of the caloric which supports animal temperature, point out one of the purposes answered by the vital properties of the blood †, and all the experiments relating to secretion and the other assimilating processes, point out the other purposes of its vitality. It possesses vital properties, not for the purpose of acting on other parts, but for that of duly responding to the inanimate agent, which acts on it in all these processes; for that the secreting and other assimilating processes depend on the action of an inanimate agent, appears from the experiments which prove that they depend on the nervous influence, which has been shown by direct experiment to be capable of its functions after it has been made to pass through other conductors than the nerves ‡, and cannot therefore have the properties of a vital power; to say nothing of those experiments by which it has been shown that all its functions may be performed by an agent which operates in inanimate nature §.

With regard to those functions by which the intercourse of the sensitive parts of

* Philosophical Transactions for 1817, 1822, 1827 and 1829; and Experimental Inquiry, Part. II. chap. xii.

† Experimental Inquiry, Part. II. Experiments 80, 81, 82, 83, 84, 85 and 86.

‡ Philosophical Transactions for 1822, 1829 and 1833; and Experimental Inquiry, Part. II. chap. xii.

§ Ibid.

the brain and spinal marrow with the external world is maintained, it is evident that the organs of the external senses are excited by inanimate agents external to our bodies, and that the muscles of voluntary motion are capable of influencing those agents; and we know that the impressions made on the external senses are propagated, and the muscles of voluntary motion excited, by the nerves, whose powers, as appears from the experiments just referred to, depend on an inanimate agent.

While the results of these experiments remain undisputed, if we assert that the nervous influence is a vital power, we must allow that such a power may exist in a mechanism wholly different from that to which it belongs in the living animal, and that all the functions of a living power may be performed by an agent which operates in inanimate nature; positions, which I believe no man, acquainted with the laws of the living animal, will be hardy enough to maintain.

Such, then, it would appear, is the nature of our frame. The sensitive parts of the brain and spinal marrow which are at once the immediate organs of enjoyment, the end of our being, and the source of those powers on which our intercourse with the external world depends, are maintained by a set of organs, the functions of which are excited by certain agents which belong to inanimate nature, and operate by other sets of organs which are capable of influencing, and being influenced by, every object around us, the functions of which are also excited by an agent of the same description. And these inferences are in no slight degree strengthened by another and distinct set of experiments, to which I referred in an early part of this paper, namely, those relating to the order in which the functions cease in the act of dying; for the whole of the phenomena traced by these experiments, as will more clearly appear from what I shall have occasion to say a little lower, tend to the same conclusions. Why do the nervous and muscular survive the sensorial functions? Why are the failing powers of life maintained in the organs of the two former classes of functions, after all trace of them is lost in the last class?

To the same conclusions, also, I cannot help thinking the following very simple train of reasoning might, without the aid of experiment, have led us. Although a single fact is often sufficient to establish the truth, when it is once arrived at, we almost always find others ready to give it their aid.

The phenomena of the three classes of functions above enumerated, namely, those by which our bodies are maintained, those by which the sensorial organs are influenced by the external world, and those by which they influence it, appear themselves sufficient to evince that the agents employed in their production partake of the nature of that world. Were not this the case, is it possible that the analogy between them and its phenomena could be such as we find it? Can we conceive a stronger analogy than the phenomena of inanimate nature bear to the propagation of an impulse along a nerve? Do not a thousand inanimate agents excite the muscular fibre in precisely the same way as the nervous influence does*? and it would be difficult to believe that

* See the first of my papers in the Philosophical Transactions for 1833.

the agent which operates in the formation of the secreted fluids from the blood and the other assimilating processes, is of a nature essentially different from that which effects similar changes in the laboratory of the chemist, even if the facts to which I have had occasion to refer had not been experimentally ascertained; but these facts, bearing more directly on the question, necessarily make a stronger impression.

Let us for a moment glance at those phenomena in which we are assured that no inanimate agent interferes. It is evident that the organs to which impressions made on the nerves are conveyed, must be those organs from which the nerves in question originate and derive their power. The sensitive nerves must communicate the impressions made on them to the sensitive parts of the brain and spinal marrow. It therefore follows that the sensorial functions, consequent on impression made on the nerves of the sensitive system, are the effects of the influence of the nerves on those parts of these organs. What are the results of this action of one vital part on another? Can we see any analogy between the phenomena of inanimate nature and pleasure or pain, the excitement of the feelings, or of the powers of reflection?

We thus readily perceive why the sensorial functions are the first which cease in dying. The stimulating parts of the blood are still present to excite the vessels, and the nervous influence, as appears from direct experiments above referred to, is still present to support the functions of the assimilating organs; but the sensorial functions being the results of vital parts acting on each other, as the vital powers fail, the powers of the parts acted on, and those which act upon them failing together, these functions necessarily cease. Here there is no inanimate agent present, as in the case of the nervous and muscular functions, to excite the languid powers of life*.

It is evident that in such a system as that I have been describing, there are two principles, either of which may determine the decay of all the sensitive functions. These, the functions by which the intercourse with the external world is maintained, may become incapable of their work, or those functions which maintain them, of their office. In the only natural death, that of old age, we have seen both these principles of decay in operation. The sensitive functions are gradually dimmed, and the vital functions gradually become less active.

Life, without much violence done to language, has been called a forced state. It consists of excitable parts called into action by suitable stimulants. These stimulants, it appears from what has been said, are all of an inanimate nature, for although the sensorial can only be excited through the nervous system, the action of the former, it

* It is observed in my Inquiry into the Laws of the Vital Functions, that in the most sudden death arising from causes which instantly destroy the powers of the nervous system, all the vital powers are at once destroyed; but this is only to be understood comparatively. The time in such cases required for their destruction is short; but in all the instances I have witnessed, the same succession, however rapid, could be observed. It was still evident that the muscular and nervous survived the sensorial functions. After the sensorial functions had ceased, slight flutterings of the heart and fleeting contractions of the muscles of voluntary motion could still be observed.

is evident, equally, though not so immediately, depends on the agents which excite the latter. Hence the harmony which exists between the living powers of the animal body and the powers of inanimate nature. There is nothing in common in the nature of these powers; but the organs of the former, being composed of the same materials with the world which surrounds us, can be excited by no means but the agents which operate in that world; and on what principle could we expect any other result?

These organs themselves are a part of inanimate nature. Deprived of their vital powers, they may still, as far as we see, be perfect in all their parts. On what their vital powers depend, we know not. In the study of these powers, and the relation they bear to the other powers of nature, we must be satisfied to take the facts as we find them. And what other knowledge have we of the inanimate powers themselves? Do we know more of the nature of gravitation or electricity than of life? It is the properties, not the essences, of things which are the objects of our senses. Our nature must be changed before the latter can be made a subject of inquiry. Life is a certain train of phenomena, depending on the peculiar state of its organs, produced by the action of the same agents, which operate in other parts of nature, on the material organs of our frame. We may arrange these phenomena in the way that best assists the memory, and best shows their relation to each other and the other phenomena of nature; but no task can be more hopeless than the attempt to proceed one step further, either with respect to the living powers or any other principle of action. Such an attempt is beyond not merely the limits, but the nature, of our minds. It is the blind attempting a knowledge of colours.

When we say we understand any of the phenomena of nature, we only mean that we are able to class them with other similar phenomena. We say that we know why a stone falls to the ground, because we class its fall with the other phenomena of gravitation. With regard to the phenomena of animal life, we at once see the limit of our inquiries, because it is self-evident that these phenomena exist nowhere but in the living animal, and consequently that there is no more general principle to which they can be referred; a position so evident that it is difficult to understand how it could ever have been overlooked.

It is customary to speak of life as a subject of peculiar mystery. But if what has just been said be correct, we have precisely the same means of acquaintance with it as with the other powers of nature. Its phenomena are as open to observation and experiment as the phenomena of any of these powers; and we possess no information respecting any of them but such as is derived from those sources. The greater appearance of mystery arises, not from the greater obscurity of the nature of life, but from its phenomena bearing less analogy to those of the other powers of nature than these bear to each other; in consequence of which the former are less familiar objects of contemplation. Simple as such observations are, they cannot be regarded as superfluous, when we see them overlooked by such writers as HARTLEY, HUNTER, and others of almost equal name.

We cannot be surprised that the inanimate agents which are incapable of any change that unfits them for their office, should at length effect a permanent change in the vital parts on which they operate, of all parts of nature the most changeable. Hence the death of old age.

The sensorial functions we have seen fail first, because their organs are removed from the immediate action of the inanimate agents which still excite the organs to which they are directly applied; but for the same reason, it is in the latter, the organs of the nervous and muscular systems, that the decay begins. Their powers are gradually impaired by the operation of the inanimate agents which excite them, and the sensorial powers, as appears from all the phenomena of our decay, only fail in consequence of their failure; but as a certain vigour is necessary to render the latter capable of maintaining the sensorial functions, these necessarily cease before the total extinction of those which maintain them.

IN the forms of violent death which have been considered, the offending cause makes its impression on the organs of the sensitive, in those which remain to be considered, on the organs of the vital system.

IT is evident from what has been said of the nature and relations of the functions of the living animal, that there is one class of the causes of death which is necessarily confined to the vital organs. On them, we have seen, the inanimate agents on the operation of which life depends, make their impression. Those which impress the organs of the sensitive system excite only the functions by which our intercourse with the external world is maintained, and consequently may cease to operate without at all endangering life. But the withdrawal of the agents which excite the vital organs as certainly proves fatal as the loss of power in these organs themselves.

The operation of such causes is too simple to require any comment. It is evident that the want of food must destroy the digestive and other assimilating functions; that of air, the functions of the lungs; and the loss of blood, to a certain extent, those of the heart and blood-vessels.

THE other causes which belong to the forms of death I am now to consider, operate in a manner analogous to the offending causes which make their impression on the organs of the sensitive system; for although the vital organs are not subject to the same species of exhaustion with those of the sensitive system*, like them they may be debilitated either by the excess of the stimulant, or the more direct, effect of the agent, according to the degree in which it is applied. The excitement of fever terminates in debility of the heart and blood-vessels, or where the cause is more powerful, as we see in the worst forms of typhus, it may directly impair their powers;

* See my paper on Sleep in the Philosophical Transactions for 1833.

and similar observations apply to the effects of the offending cause on all the other vital organs. Although such are uniformly its effects on the parts on which it operates, its effects on the system in general, in consequence of the sympathies of our frame, admit of greater variety. These also may be divided into two classes.

In considering the second of the forms of death in which the impression of the offending cause is confined to the organs of the sensitive system, it appeared that when it is both violent and sudden, it immediately, in consequence of the sympathy of the sensitive and vital parts of the brain and spinal marrow, and the influence of the latter on the heart and blood-vessels, destroys the circulation*; whereas, when less powerful, it proves fatal, not only more slowly, but also in a different way. A similar observation applies to the causes of death which make their impression on the vital organs; for the circumstance of their being more or less violent and sudden, or making their impression on an organ more or less immediately essential to life, not only renders their effects more or less sudden, but essentially influences their nature.

When the cause affects an organ immediately essential to life, and is of such power as at once to destroy its function, death, depending wholly on the loss of that function, may be instantaneous; but when the cause operates less rapidly, or affects organs less immediately essential to life, death is not only more protracted, but the various causes of continued irritation which attend derangement of the vital, influencing the state of the sensitive system, it often arises as much from the impression made indirectly on the organs of this system, as on those to which the cause is applied, and sometimes more so. Thus, any cause which suddenly destroys the function of the heart or lungs, at once proves fatal, and the cause of death is simply the loss of a function immediately essential to life; but a loss of function in the intestines produces, not immediate death, but a series of causes of irritation, which exhaust the powers of the sensitive system, and death arises as much from this cause as from loss of function in the seat of the injury. Thus a blow on the stomach may instantly prove fatal by the impression it makes on the vital parts of the brain and spinal marrow without producing any other cause of derangement†; but inflammation of that organ, by the torture it occasions, often exhausts the powers of the sensitive system, before the inflammation has time to run the course that would prove fatal by its effects on the stomach itself.

We observe the same thing in a more remarkable degree where the organ is still less immediately essential to life, and the disease consequently is more protracted. It is in this way that stone in the bladder proves fatal. If such local mischief do not occur as disturbs the usual course of the disease, life terminates in the same way as from torture, only more slowly as the suffering is less severe and continued, that is, in a morbid debility of the powers of the sensitive system, more or less, according to circumstances, affecting the vital parts of the brain and spinal marrow, and the last

* Philosophical Transactions for 1815; and Experimental Inquiry, Part II. chap. ii.

† Ibid.

symptoms, as in cases where the cause of the disease makes its first impression on the sensitive organs themselves, are those of nervous apoplexy.

In this way death from causes of injury, making their impression on the vital organs, often approaches very nearly to the nature of the other forms of death which have been considered; and in almost all instances, with the exception of the most sudden, this is more or less the case; and consequently many of the observations made respecting the other forms of death, apply to the form I am now considering, particularly those relating to the gradual diminution of sensibility and perversion of taste which so generally precede, and more or less reconcile us to death.

I have already had occasion to observe, that even in some protracted cases there is little of this tendency. This, of course, is most apt to happen where the sensitive system is least affected, and therefore where the cause of injury makes its impression on vital organs of little sensibility,—on the lungs, for example, organs of peculiarly dull feeling,—a wise provision, for the air is so variously impregnated, and in so many ways which it is impossible to guard against, that were their sensibility acute, we should be exposed to constant causes of irritation. It is probably from its being so little so that, of all our organs, their sensibility is least apt to be increased by disease, the common effect of continued irritation. Those who have been troubled with carious teeth know how sensible the gums, parts of comparatively dull feeling, often become in disease. Even the most severe inflammation of the lungs may exist without pain, although the difficulty of breathing, cough and fever, which attend it, sometimes exhaust the feelings as much as pain. In its more chronic forms, however, it is often but little distressing even in these ways; and I have seen a few cases of pulmonary consumption, in which the sensibility and relish of life continued so entire, long after the patient was sensible of his approaching end, as to produce a state of mind peculiarly distressing, differing but little from that of those who look forward to what is called a violent death. This, however, is rare. In all serious and particularly tedious illness there is generally sufficient bodily suffering and perversion of taste, more or less, to blunt the sensibility, and in some measure to wean the patient from the love of life; and we generally find the grief and agitation on the part of the relatives, and on that of the patient, a degree of indifference and composure, which those who have only experienced the feelings of healthful vigour are at a loss to comprehend. Even the dread of death at length prepares us for it. The feelings of the criminal who is hanged on the instant are those of horror; of him who has languished in prison, of resignation.

But of whatever kind and degree the previous suffering may be, and by whatever cause produced, the last act of dying, in the common sense of the word, is still but the extinction of the sensibility, and consequently the termination of all suffering; and, as might from its nature have been foretold, so calm in general is this last act, that the most anxious observer often finds it impossible to ascertain the moment at which it takes place.

The circumstance which has given rise to our notions respecting the sufferings of our last moments is, that in certain diseases there is a convulsive action of the muscles at the time at which the sensibility is extinguished. But these are not acts of volition. The laws of our nature tell us that they are not the effects of suffering; and we never see in the patient any indication that he suffers. They are of the same nature with the convulsive motions of the epileptic, of which he is wholly unconscious. Were they indications of a struggle of feeling, necessarily connected with the last act of dying, as has been supposed, they would be a constant symptom; whereas they only occur under certain circumstances of the constitution or the disease. One of the least painful of violent deaths is that from loss of blood; yet here this struggle very uniformly attends the last act of dying, according to the common acceptation of the term; and it is evident that here the sensibility, in consequence of the failure of circulation, is almost extinguished before this involuntary action of the muscles takes place*.

It is generally supposed that the struggle of the criminal after the drop falls is the measure of his sufferings. The most vigorous necessarily suffer most, because in them the sensibility is with most difficulty extinguished; but it is not uniformly in them that this struggle is greatest. We have reason to believe that it is little, if at all, connected with the feelings of the sufferer. All such convulsive motions are of the same nature with what is called *subsultus tendinum*, so apt to occur in fever, even while the sensibility is little, if at all, impaired, but which gives no uneasiness but what arises from the motions of the limbs it occasions.

The causes of disease under various circumstances must act more or less interruptedly. In some cases their operation wholly ceases, and is renewed at intervals, causing the disease to intermit. There is a principle in the animal body on which the cure of all diseases depends, termed by writers the *vis medicatrix*, in consequence of which the more immediate effects of the offending cause are followed by others which tend to counteract them. If the surface of the bowels, for example, be irritated, a more copious secretion of their fluids and an increase of the peristaltic motion are excited, by which the irritation is relieved and the cause of injury expelled; and although there are few cases in which the operation of this power is so simple as in this instance, in all diseases its effects may more or less be observed, and a great part of the object of medical treatment, as far as the nature of the disease is understood, is to assist and

* It may appear at first view that our condition would have been improved had we not been endowed with the sensibility which often renders disease so great an evil; but in the same proportion as our ease would have thus been consulted, our danger would have been increased. It is by the quick sensibility of our frame that we are warned of a thousand dangers, and enabled to guard against them. Such is the imperfection of our present state, that we enjoy few advantages which have not occasionally their accompanying evils. But there is no instance but that of sleep, which is rather an imperfection than a positive evil, in which the evil necessarily exists; and thus we have reason to believe that the sum of enjoyment is the greatest of which that state admits. The species is protected at the expense of the individual.

regulate its operations*. We find even in those diseases which are of the most continued form, partly from its operation and partly from the cause of the disease acting more or less interruptedly, more or less evident remissions. Hence, and from a thousand accidental circumstances which influence the course of disease, and many of which it is impossible to trace, we find in diseases of continuance, that at one time the stimulant, at another the sedative effect prevails. Thus the sufferer appears at one time to be sinking, and at another to revive, without our always being able to trace the cause of such variations. All this the complicated nature of the animal body, and the various ways in which it may be influenced, would lead us to expect. We might also be led to expect that it would sometimes happen that when the excitability is nearly exhausted, such a cause of excitement might under certain circumstances occur as would suddenly exhaust that which still remains, and thus, by causing a sudden but temporary revival, prove the prelude to death. Hence what is termed a lightening before death, on which so many superstitions have been founded. This is seldom strongly marked. That it occasionally is so, we have sufficient evidence, and that it should be so, is perfectly consistent with the laws of the animal economy; but it will appear from what has been said, that, like the convulsive motions I have been considering, it has no essential connexion with the act of dying, and is not the consequence, but the cause, of its immediate approach.

Before I proceed to the last part of the subject, namely, the order in which the nervous and muscular functions cease, on which a very few remarks will be sufficient, I shall shortly recapitulate the leading features of the different forms of death, without recurring to the other parts of the subject, which are too numerous to admit of recapitulation; and make such additional observations as the recapitulation suggests.

WE have seen that the forms of death,—for, as I have already had occasion to observe, the whole operation of the causes of decay in strict language constitutes the act of dying,—may be arranged under five heads.

1. The only natural death, that from old age, where all the powers of life, in consequence of the operation of the agents which excite their organs, gradually decline, and death is only the last sleep, characterized by no peculiarity, in which these powers,

* Here, as in other instances, that imperfection of our present state, which we have reason to believe inseparable from it, appears. Nature, for example, relieves inflammation sometimes by exciting discharges from the inflamed part, sometimes by the process of suppuration; but she still employs the same means, although the effusion or suppuration by which the inflammation is relieved, from the nature or situation of the part affected, generally proves fatal. Such is the case in croup, the disease termed internal water of the head, inflammation of many vital organs, &c. In these cases it is the object of the physician to cure the inflammation by artificial means before it has time to run to such terminations. In other instances, as in some external inflammations, his object is to promote these operations of the *vis medicatrix*, as the least injurious way of removing the disease.

partly from their own decay, and partly from the lessened sensibility increasing the difficulty of restoring the sensitive system, become incapable of this office, in consequence of which the individual awakes no more; for it is to be recollected that it is not in the commencement, but in the progress of the last sleep that what we call death takes place. In its commencement, we have seen, the sleeper may always be roused by stronger stimulants than those which preceded it.

All the other forms of death, it appears from what has been said, may be regarded as more or less violent, some adventitious cause disturbing the natural process. They were divided into two classes; in the one the offending cause makes its impression on the sensitive, in the other, on the vital organs. The former were divided into those cases in which the debility which precedes the total loss of sensibility, arises from the excess of the stimulant operation of the offending cause, and those in which it is the direct effect of that cause; the latter into those causes in which the vital powers fail in consequence of their organs being deprived of the stimulants which excite them, and those in which the offending cause makes its impression on these organs themselves, the power of which, analogous to the operation of the offending cause on the sensitive organs, is destroyed, either by the excess of its stimulant, or its more directly debilitating operation, according to the nature or degree of that cause. Thus are induced,

2. The death which in its nature most nearly resembles the death of old age, that from excessive exhaustion of the sensitive system from the operation of stimulants of greater power than this system can bear, notwithstanding the intervals of such imperfect repose as their continued operation admits of, without the supervention of disease; which, not being capable of relief from the continued action of the vital parts of the brain and spinal marrow, by sympathy spreads to them, the affection of each system increasing that of the other, till all the powers of the sensitive system are destroyed.

3. The death in which disease of the sensitive system arises, not from causes overexciting, but directly debilitating it; the debility they produce, being of the same nature with that from excessive excitement, and running the same course as in the second stage of the preceding form.

4. The death which arises from the privation of the natural stimulants of the organs of life; and lastly,

5. That which arises from diseased states of those organs, analogous to the states produced in the organs of the sensitive system by the causes which make their impression on them.

IF the foregoing include all the modes of decay, the physiological nature of death in its various forms is referable to very simple principles. In the natural decay the excitability of the organs of both the sensitive and vital systems is gradually impaired by stimulants, which, whether existing within our bodies or making their impression from without, belong to inanimate nature; for it is by the impression of such stimu-

lants alone that the functions of life are maintained. In the different kinds of violent death, with the exception of the death which arises from a failure of the natural stimulants of the vital organs, which is comparatively rare and extremely simple in its nature, we find the excitability of one or both of these systems, or some parts of one or both of them, capable of influencing all the others, more quickly destroyed by the continued operation of causes which either stimulate beyond the limits of health, or, applied beyond the limits of their stimulant operation, destroy the powers of life, either by directly destroying the powers of the sensitive system or depriving it of those powers by which it is maintained. All these causes, it is evident, tend to the same effect, the extinction of the sensibility, which constitutes death according to the common acceptation of the term, the immediate cause of which, therefore, exists in the sensitive parts of the brain and spinal marrow.

Thus it appears that, in every instance,—for it will be found, I believe, that there is no case of death which may not be referred to one of the foregoing heads,—what is called death and the loss of sensibility are one and the same, and therefore that the last act of dying can in no instance be an act of suffering; and this we have seen confirmed by direct observation, as far as the observation of the bystander can confirm it; to which may be added the experience of the sufferer himself, because those who, from submersion or other similar causes, have passed that portion of the act of dying where suffering can alone take place, and who have, as above explained, been in the common sense of the word dead, and in consequence of the degree of vigour still remaining in the vital organs restored by inflating the lungs, declare that they had been sensible of no suffering but such as arises from a less degree of the same cause which in them had wholly extinguished sensibility; an observation well illustrated by the circumstance, that those who are restored by artificial respiration, and could not have returned to life without this aid, and those whose breathing, not having been long enough suspended wholly to destroy the sensibility, and who consequently, although to all appearance equally insensible, in a short time after the cause is removed, breathe spontaneously, give precisely the same account of their sufferings.

In those in whom the sensibility has been extinguished by submersion, it is in the first part of the process by which they recover, not in the last part of that by which they lose it, that they suffer, which it is not difficult to explain.

In the latter the sensibility is almost lost before it is wholly so. The apoplectic who has still feeling enough to breathe, who may still be roused to remove the extreme cause of suffering which the want of a supply of air in the lungs occasions, may be insensible to all other causes of excitement; for in proportion to the immediate importance of that supply, is the feeling which impels us to obtain it. We have instances of the hand being voluntarily held in the fire; but none, of the breathing voluntarily stopped till the lungs were injured. The circumstance of the breathing, independently of artificial means, being finally lost, is a proof that the sensibility is wholly extinguished; and as its extinction in such a case must be more or less gradual, the

capability of acute suffering, it is evident, must be lost some time before the period at which the want of air in the lungs cannot even be felt.

In the act of recovery, on the other hand, the sensibility necessarily begins to revive before the vital organs perfectly recover their functions after so severe a shock. The sensitive, on its revival, thus finds the vital system still more or less in a state of disease, to which the former, as its powers increase, is every moment becoming more sensible; for while the powers of both remain, all derangement of the vital is felt by the sensitive system; a wise provision, by which we are warned to guard against causes of danger confined to the former.

IT will readily occur from what has been said, to those whom I have the honour to address, that under certain circumstances more than one of the preceding forms of death may concur. The first indeed, the death of old age, may be regarded as so far a combination of more than one of the other forms, that the cause makes its impression on both the sensitive and vital systems; but its effects on both, as appears from all that has been said, are essentially different from those of disease.

In certain cases the cause of disease makes its impression on both systems, and then more than one of the last four forms concur. This, I have already had occasion to point out, necessarily happens from mechanical injury of considerable portions either of the brain or spinal marrow. When both systems are directly impressed by the cause of the disease, which is comparatively rare, it produces, as follows from what has been said, a combination of the third and fifth, or second and fifth forms, according as its effects are more or less sudden and severe.

SUCH in different cases, is the varied course of our decay previous to the moment at which the sensibility is extinguished, emphatically called that of death, because it completes the decay of the sensorial powers, and leaves us only those which we possess in common with the vegetable world; for the vegetable, like the animal, can convey its juices, form its secreted fluids, and in some instances move its limbs, if proper stimulants be applied; an additional argument, it might be shown, if any were required, for all such functions being the effects of inanimate agents acting on living parts.

After the removal of the sensorial functions, none remain to us but such as are maintained by the immediate action of those agents. Our bodies are hastening to be mingled with the matter of inanimate nature. They retain only those powers which immediately depend on its agents, and these are rapidly failing, because, for reasons which have been pointed out at length*, the due application of those agents in the more perfect animals cannot long survive the loss of the sensorial powers.

The power of organizing the elements of inanimate nature belongs, and some have

* Philosophical Transactions for 1829; and Experimental Inquiry, Part II. chap. xi.

supposed exclusively, to the vegetable world; but as we see plants, the mushroom tribe, possessed of no organizing power, and therefore, like animals, nourished only by matter already organized, some of the lower species of animals, on the other hand, seem to possess this power. Thus, it would appear that there is a class of animals and of plants in which the animal and vegetable, in this essential respect, exchange their natures. As the animal becomes imperfect, and approaches the nature of the vegetable, the sensorial powers dwindle, and the lowest animals appear to extract their nutriment from air and water, which, being generally diffused, are at hand, and consequently obtained without any sensible effort on the part of the animal. His life, therefore, although not independent of the external world, is, like that of the vegetable, independent of any act of volition. As we rise in the scale of animals, the sensorial powers increase, and, in the same proportion, become more essential to existence. From those animals which obtain food without any act of volition, we come to those who can only obtain it by such an act, but who still without any act of this kind obtain the influence of the air, yet more immediately necessary to their existence. We arrive at length at the most perfect class, which can neither obtain food nor air, except by an act of the sensorium. In them the sensorial power is as necessary for the inhalation of the air, as the ingestion of the food. When sensation ceases, they as certainly cease to breathe as they cease to eat. Thus it is that in this class of animals the due application of the inanimate agents on which life depends, cannot long survive the loss of the sensorial functions.

AS we have been enabled, by the aid of the experiments referred to in the foregoing paper, to trace the steps by which the sensibility in the various forms of death is extinguished, that is, of our decay up to that moment which has for very evident reasons obtained the name of death, by the same means we may with more ease trace the steps by which the remaining powers of life are extinguished.

AS the powers of life fail, we have seen, the first functions which cease are those which wholly depend on these powers. The others, being the results of inanimate agents acting on vital parts, continue as long as those agents are supplied, for the purpose of exciting their organs. The first of these powers which fails is evidently the power of the capillary vessels, because their function continues as long as any blood can be supplied to them from the larger arteries. The circumstance of the action of the capillaries only ceasing when the larger arteries are empty, affords a proof that the assimilating processes, without which their power would fail, are still more or less in a state of activity. These processes, we have seen, are immediately dependent on the vital parts of the brain and spinal marrow. The due mechanism of every part, it appears from direct experiment, depends on the action on the blood of the agent they supply. When the capillaries can no longer supply the blood on which it acts, it is evident that the functions of this agent must cease, and conse-

quently that those parts of the brain and spinal marrow, by which it is supplied, being thus deranged, their powers must cease also*. These are the last of the powers of life which fail, and thus the body of the more perfect animal is left subject to the laws of inanimate matter. The first functions which cease are those of the sensitive parts of the brain and spinal marrow; the last, those of the vital parts of these organs.

* In the first of any of the more perfect animals, the nervous influence must have been supplied from without, or the rudiments of the organs which supply it and those of the sanguiferous system must have been simultaneous creations, because neither is capable of producing the other, the functions of each being inseparable from those of the other. We have seen that it is a necessary inference from direct experiment, that while the vital principle is unimpaired, the powers of circulation, provided the blood be duly exposed to the influence of the air, are capable, with the aid of voltaic electricity, of all the assimilating functions. No other powers are required for the maintenance and growth of the animal body.

We have reason to believe that the vital parts of the brain and spinal marrow may, like the lungs, be inactive in the fœtal state, some other means in this state being employed to supply the agent which, after birth, can only be supplied by them. Well grown fœtuses, perfect in all their other parts, have been born without either brain or spinal marrow. The growth of such fœtuses must depend on the same causes as the growth of other monstrous productions in the uterus, namely, as far as relates to the brain and spinal marrow, on the powers of the mother alone, how applied it is impossible to say.