XVIII. *On the Powers on which the Functions of Life in the more perfect Animals depend, and on the Manner in which they are associated in the production of their more complicated results.* *By* A. P. W. Philip, *M.D. F.R.S. L. & E. &c.*

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In considering the powers of life, I shall in the first place inquire into the seat, the functions and the nature of each of these powers; and then point out the manner in which they are associated in the production of their more complicated results*.

OF the powers of the living animal the simplest is that by which the motion of its various members is effected, and which essentially contributes to all its more complicated functions, the contractile power of the muscular fibre, the healthy action of which is not a state of uniform contraction but of a constant and generally rapid suc-

* The following paper comprehends the results of a task, not of a few months or years, but, with the exception of the time devoted to the more active duties of my profession, of the greater part of not a short life. As far as I can, to render what I have done useful, it is necessary that the various facts should be compared, and thus the inferences they afford ascertained. They are dispersed through so many publications, eleven papers in the Philosophical Transactions, published in the course of twenty years, an Inquiry into the Laws of the Vital Functions, a Treatise on the Influence of Minute Doses of Mercury in restoring the Functions of Health, my Gulstonian Lectures on the more obscure affections of the Brain, &c., that although they are frequently referred to, it has almost always been, more or less, under mistaken views; because the writer, in commenting on one part, has been unacquainted with others with which it is intimately connected, for in so protracted an investigation, few will take the trouble to keep pace with the inquirer.

It will appear from the references in the following paper how each of the various facts, dispersed through so many publications, has contributed to fill up the great outline of the laws that regulate the animal functions, which has been the object of my labours, and from which the topics of the day have never induced me to swerve. It is evident that this outline must be ascertained, before the functions of particular organs can be successfully investigated; all of which more or less depend on the general laws of our frame.

The following I believe is the first attempt which has been made to ascertain experimentally the seat, the functions and the nature of all the powers of the more perfect animal, and the various relations they bear to each other, by which, several and in some functions all of these powers being enabled to cooperate, their more complicated results are effected. In the latter part of the subject, I have found much care required in rendering the language sufficiently explicit; and if in any instance I have failed in this attempt, I hope it will in some degree be ascribed to the very complicated nature of the subject, arising from the great variety of facts on which the conclusions are necessarily founded.

It will be admitted with respect to the conclusions themselves, that the circumstance of the present inquiry embracing the whole of the subject is in favour of their accuracy; because in that case, and where, as in the present instance, all the parts are intimately connected, few inferences consequently resting on any single position, an error may betray itself in so many ways, that it can hardly escape detection.

cession of contractions and relaxations. Its permanent contraction we have reason to believe is always a state of disease*.

Many of the older physiologists supposed that all the powers of the living animal reside in the nervous system. HALLER was the first who, in a way that commanded general attention, maintained that the muscular power resides in the muscular fibre itself, and made experiments for the purpose of establishing this opinion.

His conclusions however were not generally admitted, and the principle, on which the point was argued, could lead to no decision. It was as easy to affirm as to deny that the remaining nervous influence is the cause of the power which exists in the detached muscle, for it was impossible to separate from the muscular fibre the minute extremities of the nerves with which it is blended, and to them it was alleged that it owes the power, which for a short time it retains after its separation from the brain, spinal marrow and larger nerves.

The only conclusive means of determining the question appeared to be an appeal to such experiments, as are capable of directly ascertaining whether the effect of the nervous influence on the muscular fibre be that of maintaining or, analogous to the effects of other stimulants, of exhausting its excitability.

It appears from the 32nd experiment, detailed in my *Inquiry into the Laws of the Vital Functions* †, that the latter is the case to a degree, that leaves little doubt respecting the result ‡; which was confirmed by other experiments, in which I found in many trials, that when the powers of the nervous system are destroyed by opium or tobacco, the loss of power in the muscles is not proportioned to the degree in which the powers of that system are impaired, but simply to the degree in which their contractions had been excited through it §; and that the removal of both the brain and spinal marrow, which we shall find are the only organs employed in the formation of the nervous influence, does not in any degree impair the action of the heart and vessels as long as the healthy state of the blood can be maintained by artificial respiration ||.

From the whole of these experiments it appears that the opinion of HALLER is correct, that the power of the muscular fibre is not derived from the nervous system, but resides in that fibre itself; a conclusion which we shall find of no small importance

* See a paper on the Nature of Sleep published in the Philosophical Transactions for 1833 and republished in my treatise *On the Nature of Sleep and Death.*

† In referring to my *Inquiry into the Laws of the Vital Functions* the reference is always to the third edition.

‡ When two sets of muscles of the same description were exposed to the action of the same artificial stimulant, and one of them at the same time to the effects of the nervous influence, it was found that the excitability of the latter was most rapidly exhausted; and this was sometimes the case to so great a degree, that in one instance the excitability of the muscles exposed to both was exhausted in half the time required for its exhaustion in those exposed to the artificial stimulant alone.

§ The fourth edition of my Treatise on Fevers and Inflammations.

|| Philosophical Transactions for 1815, and my *Inquiry into the Laws of the Vital Functions,* Part II.

in judging of the nature of the nervous influence, and consequently of other functions of the living animal beside the function of the muscular fibre.

The powers of the nervous system properly so called, which cooperate with the muscular fibre in all the more complicated functions, next demand our attention; and it will appear that there is no other branch of physiology in which the generally received opinions have been, and indeed still are, so much at variance with simple matter of fact.

That what in common language is called the nervous system embraces two distinct sets of organs is evident; because not only do the functions of the sensorial and nervous organs, properly so called, essentially differ in their nature; but, as we shall find, their localities also are different. Now it has generally been taught that the nervous functions, properly so called, only administer to those of the sensorial power; that they are limited to the conveyance of impressions to and from the sensorial organs, and to the excitement of the muscles of voluntary motion*.

I shall in the first place inquire into the nature of the functions of the nervous system properly so called, and then endeavour to ascertain to what parts of that system the powers on which those functions depend belong.

The mere structure of the parts might have led physiologists to suspect that the organs of this system possess other powers than those just enumerated. We find two distinct classes of nerves, to one of which the functions subservient to the sensorial powers evidently belong, and it has never been proved that the other at all partake of these functions. Besides, it had appeared from experiments relating to this second class of nerves, although their results were differently reported by different writers, that they must possess functions of a wholly different nature.

Such were the circumstances which called my attention to this, as it were superadded, class of nerves; and I think it will appear from the facts I am about to adduce, both what are their functions, which we shall find much more complicated than those of the former class, and why the results of the experiments just referred to have been so differently reported.

The peculiarity of structure relating to these nerves is, that, while all the former class proceed, either from the brain or spinal marrow, directly to the parts they influence or which influence them; they either enter or send branches which enter a chain of protuberances called ganglions, from which nerves are sent to the parts influenced by them. Hence they are termed ganglionic nerves, a term however, which has not been employed in a very strict sense; because, besides the ganglions just mentioned, which receive nerves from different parts of the brain and spinal marrow, there are other protuberances also termed ganglions, which are formed on particular

* See in the Report of the British Association for the Advancement of Science for 1833 a paper by Dr. Henry of Manchester; and a Dissertation on the state of Medical Science from the termination of the 18th century to the present time by Dr. Allison, Professor of the Institutes of Medicine in the University of Edinburgh, in the Cyclopædia of Practical Medicine, published in 1834.

nerves, but which appear to have no relation to any nervous filaments but those of the particular nerve to which they belong. It is therefore necessary that I should define the sense in which I use the terms ganglion and ganglionic nerve. By ganglion, I mean a nervous protuberance which receives nerves from different sources; and by ganglionic nerve, a nerve which either enters or sends branches to such ganglions, or proceeds from them, whether it have or have not any such protuberance belonging to itself. It may be stated however that there is reason to believe that all nerves, having such protuberances, contribute towards forming the ganglions in the sense in which I use the term*.

One of the most evident peculiarities of the ganglionic nerves, in the sense in which I use the term, is, that while the cerebral and spinal nerves supply the sensitive organs and the muscles of voluntary motion, the ganglionic nerves supply the muscles of involuntary motion and the other vital organs.

Haller, finding that the heart cannot be influenced through its nerves in the same way as a muscle of voluntary motion, was led to the conclusion that the former cannot be directly influenced through the nerves. But M. Le Gallois has shown that he was deceived in this inference, the heart being immediately subject to the influence of the spinal marrow; and the latter author further inferred from his experiments that the spinal marrow is not only capable of directly influencing the heart through its nerves, but that, through the same channel, it bestows on both the heart and blood-vessels all their powers; an inference refuted both by experiments already referred to, and others, an account of which appeared in the Philosophical Transactions for 1815 and has since been republished in my *Inquiry into the Laws of the Vital Functions*; and some of which were at the request of the Royal Society repeated with the same results by Mr. Clift, Mr. Clift's confirmation of them being published in the same volume of the Transactions.

The circumstance of the brain and spinal marrow only, as we shall find, influencing the heart under peculiar circumstances is probably the cause of the fact ascertained by Haller, that it cannot be excited through its nerves in the same way as a muscle of voluntary motion, an observation which applies to all muscles of involuntary motion, a want of attention to which has misled some physiologists†.

From the whole of the experiments which have been referred to, it appears, on the one hand, that neither the brain nor spinal marrow bestows any power on the heart or vessels; but, on the other, that each of the former organs is equally capable of directly influencing both, (the vessels even to their utmost extremities,) and that, not only by exciting their powers, but also by impairing and even wholly destroying them, according to the nature and power of the agent operating on the brain or spinal marrow;

* See a paper on the functions of the nervous system in the Philosophical Transactions for 1829, which was republished in my treatise *On the Nature of Sleep and Death.*

† See my reply to MM. Breschet and Milne-Edwards in the Philosophical Transactions for 1833, entitled "Some Observations relating to the Function of Digestion."

although, in their usual functions, the heart and vessels, like the other muscles of involuntary motion, obey neither of these organs, but agents peculiar to themselves*.

Thus it appeared that the ganglionic, like the cerebral and spinal nerves of motion, may administer towards the contraction of the muscular fibre, unless, what I conceive to be more probably the case although not yet ascertained, branches of the latter nerves are bound up in the same sheath with the ganglionic nerves, as we shall find there is reason to believe is the case with respect to the nerves of sensation. Physiology has been much indebted to the experiments of Sir CHARLES BELL, M. MAJENDIE and Mr. MAYO, from which it appears that the nerves of motion and those of sensation, although often bound up in the same sheath, are distinct nerves having different origins.

What are the functions which are peculiar to the ganglionic nerves in the sense in which I use that term?

This question is answered respecting one of the most important of the vital functions, the process of secretion, in papers published in the Philosophical Transactions for 1815 and 1822, and republished in the last edition of my *Inquiry into the Laws of the Vital Functions.*

It appears from the experiments detailed in those papers that when part of the eighth pair of nerves in their passage along the neck is removed, or these nerves are divided and one end of either portion is raised from its place, the secretion of gastric juice soon begins to fail in its properties; and if the animal survives for a certain time, the contents of the stomach are found not only undigested but quite dry, proving that there had been no secretion from it whatever for some time.

From these experiments we also learn how it has happened that such various accounts of the effects in the stomach of dividing the eighth pair of nerves is given by different experimentalists; because it was found that digestion was more or less completely interrupted in proportion as the divided ends of the nerves were kept at a considerable distance from each other. Even when the distance was a quarter of an inch, provided the divided ends were no otherwise displaced than in consequence of the retraction of the nerve on its division, digestion, although more or less deranged, was not interrupted, a subject to which I shall have occasion to recur. Now as this was a point which never particularly demanded attention, accident must always have more or less influenced the result.

But secretion is not the only vital function that is influenced by the division and separation of the divided ends of the eighth pair of nerves in the neck. It appears from experiments detailed in a paper, published in the Philosophical Transactions for 1827 and republished in my treatise *On the Nature of Sleep and Death*, that, under such circumstances, all the assimilating functions are so deranged that in

* See two papers published in the Philosophical Transactions for 1815, and republished in my *Inquiry into the Laws of the Vital Functions.*

many parts of the lungs, in the space of fifteen or twenty hours, not a vestige of their healthy structure remains.

Such it appears are the effects on the stomach and lungs of depriving them of a considerable portion of the influence of the brain. They are organs well adapted for such observations. In the stomach we have certain means of judging of any considerable deviation in the process of secretion; and from the peculiar structure of the lungs, they are well adapted for observations on changes of structure. That the effects are proportioned to the degree in which the influence of the brain is withdrawn, appears from comparing those of dividing and separating the divided ends of one or both nerves.

It is not however to the brain alone that similar observations apply, for it was found that depriving the stomach and lungs of the influence of the spinal marrow is attended with the same effects. When the lumbar portion of this organ was destroyed, the functions of the stomach and lungs and the structure of the latter were as much impaired as by the division and separation of the divided ends of one of the eighth pair of nerves; and when the lower half of the spinal marrow was destroyed, as much, as by the division and separation of the divided ends of both those nerves*.

It thus appears that the powers on which the secreting and assimilating functions depend reside in the brain and spinal marrow, and equally in these organs; nor does either of them act through the other in influencing the vital organs, as the brain is found to do through the spinal marrow in influencing many of the muscles of voluntary motion, the heart and vessels in every part being equally influenced by agents acting either on the brain or spinal marrow, when the other has been removed, as while both with all their connections remain†.

The question which next presents itself is, how far are they assisted in these offices by the nerves, ganglions and plexuses?

In a paper, published in the Philosophical Transactions for 1833 and republished in my treatise *On the Nature of Sleep and Death*, I have entered into this question at great length, where such observations and experiments will be found, as far as I am capable of judging, as render the following inferences unavoidable. That the nerves, ganglions and plexuses in no degree contribute to the formation of the nervous influence; the spinal and cerebral nerves being merely the means of conveying the influence of the parts of the brain and spinal marrow from which they proceed, and of conveying to these organs the influence of impressions made on their extremities; while the ganglions and plexuses are only the means of combining the influence of all parts of the brain and spinal marrow, through all parts of which the organs of the nervous power properly so called, are distributed; the nerves proceeding from the ganglions and plexuses, being the means of conveying this combined influence to the muscles of involuntary motion and the other vital organs.

* See my *Inquiry into the Laws of the Vital Functions*, Part II. † Ibid.

The question here arises, For what purpose is the influence of every part of the brain and spinal marrow thus combined to be bestowed on these organs?

This question is answered by the experiments just referred to, which prove that the influence of every part of the brain and spinal marrow is necessary to the due performance of the functions of secretion and assimilation; and by other facts to which I shall have occasion to refer, which prove the necessity of the muscles of involuntary motion being under the controul of the same power, on which these functions depend.

All of them, as we have just seen, fail when any considerable part of the influence either of the brain or spinal marrow is withdrawn, the failure of function being proportioned to the degree in which the influence of either is withdrawn, proving that the influence of every part of them is essential to the due performance of those functions*.

Important and extensive as these functions are, there is still another, hardly less so, dependent on the powers of the nervous system properly so called. Sir BENJAMIN BRODIE† proved by direct experiment many years ago that animal temperature is under the influence of the nervous system, and various observations evince that a debilitated state of the brain is accompanied with a diminished temperature.

I made many experiments on this subject detailed in my *Inquiry into the Laws of the Vital Functions*, from which it appears that in this, as in all the other vital functions, the spinal marrow shares with the brain. If the power of either organ be impaired, the temperature sinks in precisely the same proportion as the secretions are deranged. A particular organ may be deranged by preventing its due supply of nervous influence, and there may be no general diminution of temperature. The due nervous influence is prevented reaching the particular organ, but there is no diminution of the power of the brain or spinal marrow. When, on the other hand, the power of either of these organs is impaired, there is an immediate diminution of temperature.

When the lower half of the spinal marrow was destroyed the animal shivered, and would probably soon have died of cold if it had not been kept in a high temperature, and even when the lumbar portion alone was destroyed, a considerable but less diminution of temperature ensued‡.

Thus it appears, from the whole of the facts which have been referred to, that on an influence derived from the brain and spinal marrow, and not from any part, but from the whole of these organs, the secreting and more immediately assimilating functions and the maintenance of animal temperature depend. This influence therefore performs a still more important part in the vital than in the sensitive functions. In the latter we find it acting only a subordinate part; while in the former it must be regarded as the great agent, to which all others employed are subservient.

* See papers which appeared in the Philosophical Transactions for 1815 and 1827, and my *Inquiry into the Laws of the Vital Functions*, Part II.

† See the Philosophical Transactions for 1812 and 1814.

‡ *Inquiry into the Laws of the Vital Functions*, Part II.

Has the nervous influence any immediate dependence on any of the other powers of the animal frame?

The muscular, we have seen, has no immediate dependence on the nervous power, the only power on which its immediate dependence can be supposed. In like manner the sensorial is the only power on which any immediate dependence of the nervous power can be supposed.

I made an extensive set of experiments, detailed in my *Inquiry into the Laws of the Vital Functions,* to which I shall soon have occasion to refer more particularly, from which it appears that all the functions of the nervous power properly so called survive the removal of the sensorial power, with the exception, of course, of those in which that power is associated with it. After the removal of the sensorial power the nervous influence is still capable of all its other functions. It is still capable of exciting the muscles both of voluntary and involuntary motion, of, for a short space of time, forming the secreted fluids, performing the various functions of assimilation, so far as to preserve the structure of parts where it would otherwise have been impaired, and, to a certain degree, of maintaining animal temperature. The nervous, like the muscular power, therefore, is an independent power, having its seat in its own organs, and having no other dependence on the other powers of the living animal than for the due structure of those organs.

Such are the powers of the nervous and muscular systems of the more perfect animals, and the seat and functions of these powers.

They possess however two other sources of power, for the sensorial power and the powers of the living blood have no immediate dependence on either of the former powers, or on each other.

That the only dependence of the sensorial power is for the maintenance of its organs, is evident on the most cursory review of the animal economy. The nature of the functions of that power alone evinces that the living animal possesses no others from which it can be derived; and that the powers of living blood have no direct dependence on its other powers, is proved by the fact, that the blood retains its vital properties after it is separated from the body*.

With respect to the locality of the latter powers, the powers of the living blood, it appears from the fact just stated, existing in itself, must be coextensive with the functions of secretion and assimilation. At first view it would appear that the functions of the sensorial power, like those of the living blood, pervade every part of the system; the power of sensation seems to pervade the whole frame. On observing the phenomena with more care however, we find the seat of the sensorial power confined to a small space, when we compare it with that of the nervous power properly so called, the organs of which, we have seen, pervade the whole of the brain and spinal marrow.

* See Mr. HUNTER's experiments on the Blood, and the experiments detailed in the last chapter of the second part of my *Inquiry into the Laws of the Vital Functions.*

The nerves of sensation in which are included, of course, the nerves of the external senses, and the immediate organs of the sensorial powers are not parts of the same organ, but distinct parts, having different localities and performing functions of a wholly different nature; that is, the sensorium does not pervade the whole system, but belongs to particular parts. To what parts has never been correctly ascertained, but we know that in man they are confined to certain parts of the brain with little if any participation by the spinal marrow; although in some of the inferior animals the spinal marrow largely partakes of them, a proof that the sensorium is not as some have supposed confined to a physical point, but is of a considerable extent.

Our sensations are referred to certain parts of the body by experience alone. Hence the well-known facts that infants are not aware of the part of the body in which the cause of any sensation originates; and when a limb has been lost, at whatever part the separation is made, we continue to refer to the lost part sensations excited by causes affecting the nerves of the stump.

The function of the nerves of sensation has relation to the sensorial organs alone. The influence they convey is the means by which the sensorium is impressed by distant parts, and such is their only function.

The more perfect animals then possess four distinct powers, having no direct dependence on each other, but each we shall find indirectly dependent on the other three, namely for the maintenance of its organs.

I am now to inquire how far we can advance in determining the nature of these powers, how far they are peculiar to the living animal, or the same which operate in other parts of nature.

WE are in the habit of regarding life as a power of peculiar mystery, but do we find any other principle of action less mysterious? It is not the principle but its properties, which are the objects of our senses. A knowledge of the former is not merely beyond the limits, but the nature of our minds. Do we know more of the principle of electricity or gravitation than of life, or is there more uncertainty in noting the property of resistance to fermentation and congelation without any sensible peculiarity in the substances possessed of this property, than that of weight or light? It is not that the nature of life is more obscure than that of any other principle of action, all are equally so, but that its phenomena, being more varied and bearing less analogy to those of other principles than these bear to each other, are less familiar objects of contemplation.

The subject thus appears invested with an obscurity which does not belong to it, and the perplexity has been increased by vain attempts to remove it; attempts on principles having no relation to the laws by which the phenomena of life are regulated. What possible relation can the laws of mechanics, or any other principle which operates in the inanimate world, bear to the phenomena of life properly so called? It is as much a distinct principle as any of those which operate in that

world, and the same method which leads to a knowledge of other sciences must guide us here. There are no means but a study of its phenomena by which we can attain a knowledge of life, that is, of its properties, the only knowledge we can attain of any principle of action. But if our object be to attain a correct knowledge of it, we must first determine with accuracy what are the phenomena of life; for, in the complicated functions of the living animal, it requires not a little patience, labour and circumspection to distinguish what part depends on vital powers properly so called; and what, on a modification of the powers of inanimate nature. Even the most cursory view must convince us that many of the functions of the living animal partake of the latter powers.

Respiration is performed, that is the air is drawn into and expelled from the lungs, by means which act on the same principle as the bellows. The blood in the circulation moves on the same principle as the water in a set of water-pipes. It obeys a propelling force, and is subjected to the same laws of gravitation. The motion of our limbs is effected by the same mechanical laws, by which bodies are put in motion in the external world. Here, as in inanimate nature, velocity can only be obtained by the sacrifice of power. Similar observations apply to the various processes of secretion and assimilation. We can trace in these processes, the same chemical laws which obtain in the laboratory of the chemist; but there is at the same time in all the foregoing functions something more in operation, analogous to which we find nothing in inanimate nature.

The force indeed by which the air is drawn in and expelled in respiration operates on the same principle as in the bellows; but the powers by which the machinery is worked are the contractile power of the muscular fibre, and the power of the nerves by which it is excited. The motion of the blood depends on the same principle as that of the water in its pipes, but it is the contractility of the muscular fibre which supplies the moving power. The same observation applies to the motion of the various members of our body.

In like manner in the processes which maintain the organs of all these functions, and effect the separation of those parts of them which have become useless, and therefore noxious, while we trace the same chemical laws which operate in other parts of nature, we can perceive that they are constantly modified by the powers peculiar to the living animal; for it is not only impossible by any chemical arrangement to produce the same results in inanimate nature, but even by the principles which regulate its phenomena, to trace all the steps by which they are effected. We can neither, for example, imitate the process by which the temperature of living blood is raised above that of the surrounding medium, nor, on the principles of the chemistry of inanimate nature, trace all its steps. No position can be more erroneous than that the chemical processes of the living animal depend alone on the same laws with those of inanimate nature. The properties of life are as peculiarly its own as the properties of gravitation.

I am now to attempt to draw the line of distinction between the powers, which the living animal possesses in common with inanimate nature, and those peculiar to itself.

With respect to its mere mechanical powers to which I have just had occasion to refer, there can be but one opinion, that they are powers common to the living animal and inanimate nature; but with respect to the powers we have been more particularly considering, all of which appear at first view to be powers peculiar to the former, the question is not so easily answered. Until it is answered, however, it is evident that we cannot draw the line which correctly separates the phenomena of life from those which result from other principles of action, a line essential to an accurate view of the properties, that is, to a knowledge, of that principle.

The question which I am here to consider, then, is, how far are the sensorial, nervous and muscular powers and the powers of living blood peculiar to the living animal, or possessed by it in common with inanimate nature?

IT requires but little consideration to answer the question respecting the sensorial and muscular powers, and the powers peculiar to the living blood. Where do we find in inanimate nature a power which can be mistaken for any of them? But even the most cursory review of the functions, which, it appears from the experiments above referred to, are those of the nervous power properly so called, makes us pause. That the oxygen and carbon of the blood combine by the same agency as in the laboratory of the chemist, is a position too probable to be hastily dismissed; and if such be the case, to what other functions of the nervous influence will the same observation apply?

The following, it appears from experiments above referred to, comprehend the nervous functions properly so called.

1. The excitement of the muscles of voluntary motion in all their functions.
2. The excitement of the muscles of involuntary motion in some of their functions.
3. The maintenance of the processes on which animal temperature depends.
4. The formation of the various secreted fluids. And
5. The more immediate processes of assimilation by which the structure of our various organs is both effected and maintained.

Of these functions, the excitement of the muscles alone is the only one which may be supposed to be the effects of either a chemical or mechanical agent.

In all the healthy functions of life, however, in which the muscular power is employed, the stimulus which excites it, if we except the mere power of distension, appears to be of the former description. Even those stimulants, which maintain the functions of the alimentary canal, which, remotely depending on the stimulus of the food, may at first view be supposed to be the effect of a mechanical agent, appear to be wholly of a chemical nature. The ingesta will not excite a secretion of gastric juice unless they possess chemical properties of a certain description, and the muscular coat of the stomach is not duly excited unless the food has been converted

into a healthy chyme, the formation of which, it appears from direct experiments, depends on the healthy state of the influence supplied by the brain and spinal marrow*. In like manner, the healthy action of the intestines, as appears from a thousand observations, can only be maintained when their healthy stimulant has been duly prepared by the chemical processes which take place in the duodenum; which also depend on the influence supplied by the brain and spinal marrow. It is evident that all the other functions just enumerated are of a chemical nature. It thus appears that all the nervous functions are chemical processes, and consequently that there may be an expectation of finding an agent in inanimate nature capable of them.

It was found that in proportion as the nervous influence, properly so called, is withdrawn, all these processes fail. It is evident therefore that on this influence the changes observed depend. Whatever therefore that influence may be, all its functions in their general nature are identical with the effects of the chemical agent, whatever that agent may be, which operates in inanimate nature. This step therefore appeared to be gained. Further reasoning however was unnecessary, because it was not difficult to submit the question to the test of direct experiment.

I was thus led to consider what power of inanimate nature it was most probable might be successfully substituted for the nervous influence.

An important point had been ascertained. It had been found that of all the powers of inanimate nature, voltaic electricity is most capable of the excitement of the muscular fibre, that is, of one of the functions of the nervous influence. This indeed went but a short way towards establishing the identity of the two powers, so many other stimulants being capable of exciting that fibre. It is not to be overlooked, however, that feeble as this argument is towards proving the identity of the nervous influence and voltaic electricity, it is powerful respecting the general nature of that influence; because on the supposition of the nervous influence being a vital power properly so called, we have here a vital power possessing a property in common with a thousand inanimate agents. Is there any unequivocal instance in which any of the properties of a vital principle, properly so called, is not essentially different from those of any of the principles of inanimate nature? On the whole, the property in question was sufficient to suggest the trial how far voltaic electricity is capable of the other functions of the nervous influence.

No hope of success of course could be entertained unless the artificial agent were employed under the same circumstances, under which the nervous influence operates; that is, while the structure of the organs is entire, and their vital properties unimpaired.

Under such circumstances I substituted it for the nervous influence in the various functions of secretion and assimilation with success. It was admitted by those who

* Philosophical Transactions for 1815 and 1822, and *Inquiry into the Laws of the Vital Functions*, Part II.

witnessed the results, that these functions were as effectually performed by it, as by that influence itself; and the experiments were afterwards publicly repeated both in London* and Paris†, in the latter on a great variety of animals, and in both instances with the same results. In the first of my papers published in the Philosophical Transactions for 1829 entitled *Some Observations relating to the Function of Digestion*, several circumstances are enumerated which it is necessary to keep in view in conducting such experiments.

Only one of the functions of the nervous influence now remained which had not been effected by voltaic electricity, the process by which animal temperature is maintained. For the purpose of determining how far it is capable of this function, it was judged the most satisfactory means to expose the living blood to its effects, both in its arterial and venous state. If voltaic electricity operate on the same principle as the nervous influence, it will raise the temperature of the former, but not of the latter, which has already undergone the operation of that influence. Such was found to be the case. The arterial blood immediately rose several degrees on coming into contact with the voltaic wires, but there was no increase of temperature in the venous blood, although, in both instances, the blood was subjected to them as it flowed from the vessels; it having appeared from previous experiments that the delay of even a few minutes, although no apparent change had taken place in the blood, and no elastic fluid had been disengaged from it, prevented any rise of temperature; so rapidly do some of the properties of living blood undergo a change after its removal from the vessels ‡.

Such being the facts, I could no longer doubt that the nervous influence and voltaic electricity are powers of a similar nature, and it appeared to me that this would be most convincingly illustrated, by causing the nervous influence to pass through other conductors than the nerves; because such a fact would, independently of all others, prove that it is not a vital power properly so called, it being acknowledged on all sides that no such power admits of separation from the texture to which it belongs in the living animal.

With this view I made many vain attempts, and hardly escaped the ridicule of my associates for expecting that the nervous influence could exist in any texture but that to which it belongs in the living animal.

In the third edition of my Inquiry into the Laws of the Vital Functions, the reader

* The Journal of the Royal Institution of London for 1822. See also the London Medical and Physical Journal for May, 1820, vol. xliii. p. 385.

† De l'Influence du Système Nerveux sur la Digestion Stomachale; par MM. Breschet, D.M.P., Chef de Travaux Anatomiques de la Faculté de Médecine de Paris, &c.; H. Milne-Edwards, D.M.P.; et Vavasseur, D.M.P. (Mémoire lu à la Société Philomatique, la 2e Août, 1823.) Extrait des *Archives Générales de Médecine*, Août, 1823.

‡ See the second part of my *Inquiry into the Laws of the Vital Functions*, Experiments 80, 81, 82, 83, 84, and 85.

will find the circumstances detailed which led to the successful experiment, the result of which was publicly confirmed both in London and Paris; and those who in the first instance ridiculed my expectations, joined me in stating that such is the fact.

The cause of failure in my first experiments on this subject, was the circumstance of having made a wrong choice of the nerve on which I operated, which was a nerve of voluntary motion.

It will appear on reflection that this was a wrong choice. Before we can expect that the nervous influence can be made to pass through any other conductor than that to which it belongs in the animal body, there must exist a powerful cause soliciting it to some particular point. In a muscle of voluntary motion there can be no such cause. The nervous influence is not attracted to the muscle, it is sent to it by an act of the sensorium, carried into effect by the powers of the nervous organs, which are subjected to its influence; those organs which, on the one hand, prepare that influence, and those which, on the other, convey it when duly prepared*. The muscle is altogether passive till the influence is applied to it. But the case is wholly different with respect to many of the organs which contribute to the functions of the ganglionic system. We know from direct observation that in many of them, there is a cause continually operating, which solicits the nervous influence to them.

In these organs the living blood and nervous influence cooperate in the functions of secretion and assimilation; and it is an acknowledged fact, that when a determination of blood to secreting organs takes place, there is in the same proportion an increase of their secreted fluids, a result which cannot arrive without a corresponding supply of nervous influence. Thus we know, as indeed we had reason to expect, that the presence of the living blood in the secreting organs solicits a proportionable supply of that influence; and thus it was, that whereas, while I operated on the nerves of voluntary motion, my attempts were wholly fruitless, the very first attempt with the ganglionic nerves was crowned with success; nor, since the repetition of the experiments in London and Paris, has the fact been questioned.

If the facts I have stated be correct, we can have little doubt that the nervous influence is of a nature similar to the inanimate agent which was substituted for it; for to say nothing of the circumstance of the nervous influence being capable of existing in a texture different from that to which it belongs in the living animal, we cannot suppose that there are two distinct powers, the one of which is capable of all the effects of the other; or I would rather say, that such a supposition amounts to a contradiction in terms, because as it is acknowledged that we know nothing of any principle of action but by its properties, it necessarily follows, that by these alone it can be distinguished.

In discussing the nature of the nervous influence too much has been ascribed to electric tests, which are referred to as if they possessed a power equal to that of chemical

* See the second of my papers in the Philosophical Transactions for 1829.

tests. A correct chemical test will give evidence of what we are in quest of under all circumstances; and is therefore capable in all instances of detecting its presence, and consequently its absence also. This arises from there being but one counteracting power, that of affinity. If the affinity be stronger in the test than in any other substance, the effect of all other affinities is destroyed. We possess no such electric test, because here there may be other counteracting causes beside the power of affinity, opposing currents, for example. Besides, we know that the properties of electricity are so modified by the powers of life, as greatly to interfere with its relations to our tests. The electricity of the torpedo and other electric animals does not affect the common electrometer, yet no one has doubted its identity with the electricity of inanimate nature.

Although electric tests therefore give evidence of the presence of electricity, we cannot by their means prove its absence; a fact with which we should not have been acquainted, were it not, under certain circumstances, possible to prove the presence of electricity without their aid; that is, the presence of electricity may under certain circumstances be proved, where it is not indicated by any of the properties generally admitted to be peculiar to it.

Suppose it were said, for example, that we cannot admit that electricity is the agent in the combination of oxygen and carbon, because there is no test by which its presence can be detected; the reply of Dr. FARADAY, I conceive, would be; we cannot at present, whatever we may do hereafter, make the electricity employed in effecting this combination evident to any of our tests; but I consider its presence as a necessary inference, because I have adduced facts which prove, either that electricity is the agent in such combinations, or that nature here deviates from the simplicity observed in all her other works. Either electricity is the agent in the combination in question, or there are two kinds of chemical affinity.

Under such circumstances can any other reply avail except either disproving the facts or pointing out the fallacy of the inference?

What I have done is strikingly illustrated by the late investigations of Dr. FARADAY. It is more than twenty years since I found that voltaic electricity is capable of all the functions of the nervous influence; it now appears from the facts, on which he has founded his doctrine of electro-chemical equivalents, that electricity is the agent in all chemical processes*. According to the inferences of Dr. FARADAY therefore, the experiments, which prove that the nervous influence is the agent in the functions we have been considering, all of which we have seen are chemical processes, are sufficient to prove its electric nature; and we are now also, on the other hand, furnished with direct proof that the brain is capable of collecting and applying, even according to the dictates of the will, the electric power.

Dr. DAVY in his last paper on the torpedo† observes that, "when the brain has been

* Dr. FARADAY's papers in the Philosophical Transactions for 1832, 1833, 1834, and 1835.

† Philosophical Transactions for 1834.

divided longitudinally, the fish has continued to give shocks; when the brain has been entirely extracted, the fish instantly lost this power, though the muscles generally continued to act powerfully;" from which it appears that the electric power is not like the muscular independent of the brain, but on the contrary immediately depending on it; proving that in this, as in all the other nervous functions, as appears from the facts stated in a paper which the Royal Society did me the honour to publish in 1829, and which was republished in my *Inquiry into the Nature of Sleep and Death*, the nerves are merely the passive, the brain, one of the active parts of the nervous system.

In the foregoing positions we here find, as in other similar instances, that when truth is once arrived at, other facts, beside those which led to it, arise to give it their aid.

Dr. Davy made no experiments to determine how far the spinal marrow, the only other part of the nervous system concerned in the formation of the nervous influence, partakes of the function in question. Were we to reason from the analogy afforded by all the other nervous functions properly so called, we should expect to find the spinal marrow sharing it equally with the brain. It is not unlikely that the removal either of the brain or spinal marrow would destroy this function, as is found to be the case with respect to the more complicated functions properly termed nervous; a point which can only be determined by an appeal to direct experiment; or, like the excitement of the muscles, it may belong to either organ separately, or, which is less probable, it may, being a function of volition, belong to the brain alone.

In addition to the foregoing statements I may refer to the success which has attended the employment of voltaic electricity in those diseases which depend on a deficient supply of nervous influence*.

That we may have a clear view of the line of distinction between the sensorial and nervous powers, a more particular consideration of the former is necessary.

THE following points we have seen are made out from the phenomena of every day's experience, that the organs of the sensorial power and the nerves of sensation, in which of course are included the nerves of the organs of the external senses, are distinct organs; the former being the immediate organs of those powers, the latter the organs which excite them.

We have just seen reason to believe that the influence conveyed by the nerves which excite the muscles and maintain the secreting and assimilating functions and the due temperature of the animal body, is a power which operates in inanimate nature; because, on the one hand, we have found such a power capable of all the functions of the nervous influence, properly so called; and, on the other, that this influence is capable of existing in other textures than those to which it belongs in the living animal, proving that it is not a vital power properly so called.

Are the properties of the influence conveyed by the nerves of sensation the same

* See my *Inquiry into the Laws of the Vital Functions*, Part III., and my *Treatise on Indigestion*, 7th Edition.

with those of any of the powers of inanimate nature, or can this influence exist in any texture but that to which it belongs in the living animal?

It is enough to say that its only property is that, by which it is enabled to co-operate with the immediate organs of the sensorial power. To such a property we not only find that there is nothing analogous in any of the properties of inanimate nature; but, as will more fully appear from what I am about to say, that the organs of the sensorial power are, in their healthy functions, unapproachable by any of its agents: it is therefore perhaps unnecessary to add, that we know of no texture in which the influence conveyed by the nerves of sensation can be supposed to exist, but that to which it belongs in the living animal.

The nerves of sensation therefore belong to the sensorial not to the nervous power. They convey an influence of a wholly different nature from that conveyed by the nerves of the latter power; and the only analogy which can be traced between their function and the operations of inanimate nature is, that it is excited by impressions received from the agents of the external world; to which we are indebted for all our knowledge of that world. The action of the immediate organs of the sensorial power, we have seen, being thus excited by one vital part acting on another, and by its vital properties alone, all analogy with the operations of inanimate nature here disappears.

While the other functions of the living animal are the results of inanimate agents acting on living parts or living parts on them, in the sensorial functions we see the effects of vital parts acting on each other and that by their vital properties alone. Hence the analogy between the former and the operations of inanimate nature, and, with the exception just pointed out, the total loss of all such analogy in the latter.

Whence is it possible to conceive that such analogy can arise except from the operation of some of the agents of the inanimate world? When the phenomena of the living animal are carefully compared with the preceding facts, it will be found that in every instance, in which any analogy between its functions and the operations of inanimate nature can be traced, the interference of such an agent may be detected.

WE have now considered individually the various powers of the more perfect living animal. We have found in it, beside the mechanical powers which, it will be admitted on all hands, it evidently possesses in common with inanimate nature, four distinct powers; three of them vital powers, properly so called, that is, powers having properties essentially different from those of the agents which operate in inanimate nature. In the fourth alone we recognise one of those agents; for we find it can exist in other textures than those to which it belongs in the living animal, and that we can substitute for it one of the powers of inanimate nature without deranging the functions of life.

All these powers are employed, although in a very different way, in the construction of two systems in a great degree distinct; the end of the one being the maintenance of our bodies, of the other, our intercourse with the world which surrounds us.

In the remaining part of this paper, I am to consider the various relations those powers bear to each other in the maintenance of the foregoing systems; and the way in which these systems themselves are so related, as to form the animal body into a whole, in which no part can be affected without tending more or less to influence every other.

IN order to ascertain the seat of the power on which muscular contractility depends, it was necessary in an early part of this paper to enter on the relation which subsists between the muscular and nervous systems; and it appears from what is there said, that the nervous influence, whether in its effects on the muscles of voluntary or involuntary motion, stands only in the relation of a stimulus or directly debilitating power to the muscular fibre, according to the manner in which its organs are impressed; a result, I may observe in passing, peculiarly in accordance with all the other facts which have been stated respecting the nature of that influence, because the same observation, we shall find, applies to all the agents of inanimate nature which are capable of influencing the muscular fibre.

The relation which next demands our attention is that which subsists between the organs of the nervous influence and the living blood.

The first thing, which here strikes us, is that the blood-vessels and nerves uniformly accompany each other; from which we are led to infer that they cooperate in functions of very general necessity.

The powers of the nervous system properly so called, we have seen, are all of a chemical nature. Of this nature therefore must be all processes in which they immediately cooperate. It is evident that where such powers are employed, to render them efficient, materials must be provided on which they may operate, and there must also of course be means by which these materials are duly exposed to their action.

The materials we find in the blood, the means, employed for the purpose of duly exposing them to the action of the nervous influence, in the capillary vessels, on which, the minute extremities of the nerves, (which we know, from numberless observations, are those parts of the nervous system by which its powers are immediately applied in the functions of secretion and assimilation, as well as the excitement of the muscular fibre,) are distributed. As the central are the only parts of the nervous system properly so called, employed in the formation of the nervous influence, the extremities of the nerves are the only immediate organs of its powers in all its functions.

The motion of the fluids in the capillary vessels, as appears from many experiments related in the Philosophical Transactions for 1815 and my *Inquiry into the Laws of the Vital Functions*, depends on a power which resides in themselves, in no degree depending on the power of the heart or arteries, except as far as is necessary for the due supply of blood to the latter, which form the reservoirs, from which the capillary vessels draw their supply. When in the newly dead animal a ligature is thrown round all the vessels attached to the heart and this organ is removed, the

motion of the blood in the capillaries continues unimpaired, and only fails in proportion as the supply from the large arteries fails*; the cause of the emptiness of the latter some time after death.

By such means the materials on which the nervous influence operates are supplied and presented to it; and the means of supply, namely, the power of the heart and arteries, as well as that of the capillary vessels themselves, being, as we have seen, under the immediate influence of the same power which effects the chemical changes†, the supply is proportioned to the demand under the various conditions of the ever-changing functions; and under the same influence are the means of removal, whether of secreted fluids or solid parts become unfit for the purposes of life. Such are the circumstances above referred to, which render it necessary that the muscles, whether directly or indirectly, employed in these functions should be subjected to the same power on which depend the functions of secretion and assimilation, namely, all muscles of involuntary propulsion, that is, with a very few exceptions, all muscles of involuntary motion.

It appears from some lately ascertained facts that the secreted fluids are formed from the blood while still in its vessels, and not in the act of their separation by the secreting organs. That such must necessarily be the case appears from what has been said. The act of separation must be posterior to the changes effected by the chemical powers of the nervous influence. It is only while the blood is still in its vessels that it can be exposed to their operation; and we have reason to believe that it is only as the due changes have been effected, that is, only as the secreted fluid has acquired its due properties, that it applies the due stimulus to the vessels by which it is discharged: on the same principle that the due action of the intestines, by which they discharge their contents, is not excited if these contents have not acquired their due properties by the chemical processes which take place in the stomach and duodenum.

Such are the nature and functions of the nervous power, and its relations to the muscular power and the powers of the living blood. When we turn to the sensorial system, we find ourselves in a new world. Here voltaic electricity, which we so successfully substitute for the nervous influence, can do nothing. The immediate organs of the sensorial power, we have seen, are as it were hedged in and defended from contact with any of the agents of inanimate nature.

On the one hand, we find the nerves of sensation, which so far partake of the nature of the external world, that they are capable of receiving and propagating impressions from its agents, but in all other respects are allied to the organs with which they are associated. By their vital powers they influence the immediate organs of the sensorium, and the functions thence resulting are the effects of one vital organ influencing

* See a paper on the powers of circulation in the Philosophical Transactions for 1831 republished in my *Inquiry into the Nature of Sleep and Death.* See also my *Inquiry into the Laws of the Vital Functions,* Part II.

† See experiments detailed in the Philosophical Transactions for 1815 and 1822, and my *Inquiry into the Laws of the Vital Functions,* Part II.

another, and that by its vital properties alone; for it is evident that the properties operating here have nothing in common with those of any of the principles of inanimate nature. In the results consequently, we have seen all analogy with the phenomena of these principles, for the first time, lost; and necessarily so, none of the properties of the agents of that world being immediately employed in their production.

The nerves of sensation, it appears from what has been said, convey not the nervous influence properly so called. The influence they convey is of a nature essentially different from that by which the muscles are excited and the functions of secretion and assimilation maintained. They sufficiently partake of the nature of the sensorial organs to be capable of directly impressing them, and thus the latter receive all their impressions whether originating from without or within our own bodies.

On the other hand,—that is, that the sensorial organs may, without contact with any of the agents of the external world, impress those agents,—a more complicated machinery is required. The various nerves of sensation are the only means required for conveying impressions to these organs; but so simple an apparatus is not sufficient to convey to, and impress on, the materials of the external world, the dictates of volition. The powers of the nervous system are here called into operation by the sensorial powers, to which they are subjected; for it appears from many experiments, detailed in the Philosophical Transactions for 1815 and in my *Inquiry into the Laws of the Vital Functions*, that as the muscular is independent of the nervous power, but subjected to its influence, the nervous is independent of the sensorial power, but, in like manner, subjected to the influence of this power. In the case before us the nervous, influenced by the powers of the sensorial organs, supply a certain set of nerves with the stimulus which excites the muscles of voluntary motion, the immediate agents by which the materials of the external world are impressed.

I have had occasion to refer to the great variety of the phenomena of life, as one cause of their apparent obscurity. Such is their variety that we are at first view lost in attempting any arrangement or even enumeration of them. An essential step towards their arrangement, as appears from what has been said, is their division into those which are the immediate results of the cooperation of the principle of life with the principles of inanimate nature, and those which have no immediate dependence on the latter powers; for all our functions mediately or immediately depend on the operations of the agents of inanimate nature. All are more or less directly excited by impressions originating in their agency.

The most purely sensorial functions, our pleasures and pains, are as dependent, though more remotely, on the excitement maintained by them as the functions of the organs immediately impressed by them. Have not the excitements of memory as much originated in their impressions, as their more direct effects on the part impressed? And when the nature of our bodies and the circumstances in which we are placed are duly considered, what other result could be expected? Our organs, being

composed of the same materials as the world which surrounds us, can only be directly influenced by agents of their own nature; and from that world, and by the medium of those organs, all the materials, not only of our acquired knowledge*, but of our enjoyments and our sufferings, are derived.

And as on the one hand, all our functions are more or less immediately excited by impressions made by the agents of the external world on organs composed of materials of their own nature, on the other, we have no power of influencing them, but through similar means. The only means of exciting our mental functions are the impressions of those agents on the organs of sense, and our only means of operating beyond our own bodies are through our organs of motion. Even when by our mental powers we influence those of other sentient beings, it is as much, though not so directly, by impressing the agents of the external world by the latter organs, as when we raise a weight or throw a stone.

SUCH is the general outline of the vital and sensitive systems; and the manner in which the various powers of the living animal are related in the formation of these systems. By the foregoing means, the nervous power maintains the vital functions properly so called; and the sensorial power is brought to cooperate with the powers of inanimate nature, powers which have no properties in common.

IT appears from the facts adduced in my paper on the Nature of Death, published in the Philosophical Transactions for 1834, that the vital and sensitive systems obey very different laws, the difference depending on the vast difference in the nature of the sensorial and nervous powers, the leading powers which pervade all their departments, and to which all their other powers are subservient.

These other powers, it appears from what has been said, are the same in both, namely, the muscular power and the powers of the living blood, and, in the sensitive system, the nervous power itself; for in this system all the other powers of the living animal are directly subjected to the sensorial power, while none of the powers of the vital system have any direct influence on it, their influence on the sensorial power being through the medium of its organs, the structure and wellbeing of which immediately depend on the vital powers.

In other respects also the laws of the two systems essentially differ. Nor will these differences surprise us, when it is recollected, as appears from the facts which have been stated, that while the leading power in the vital system is one of those powers which operate in the external world; that of the sensitive system not only possesses no properties in common with the agents of inanimate nature, but depends on a set of organs unapproachable in their healthy functions by any such agents.

When the facts adduced in the paper just referred to, and that on the Nature of

* We are born with the knowledge which is immediately essential to our existence. The infant knows as well how to suck and how to breathe as the adult. See my paper *On the Nature of Death.*

Sleep published in the Philosophical Transactions for 1833, are duly considered, it will appear that a principal cause of difference in the laws of these systems depends on the difference of the laws of excitability in the organs of their leading powers. In those of the leading power of the sensitive system, all degrees of excitement are followed by a rapid proportional exhaustion of excitability; so that the effect of the usual stimulants of life for a few hours, renders a state of inactivity essential to the maintenance of their health: while the exhaustion of the excitability of the organs of the leading power in the vital system by those stimulants, is the operation of many times as many years, the one determining the recurrence of sleep, the other the natural duration of life.

Thus it is that those, in whom, from habits of dissipation, extreme labour, or other causes, the excitability of the vital system is to a certain degree exhausted, but who as they approach middle life cease to be exposed to such causes, and during that portion of life, that is from thirty to fifty or fifty-five, feel little inconvenience from the effects of their early habits, there still being in the vital system sufficient excitability for the usual functions of life; after this period, when the defect of excitability begins to be felt sooner or later by all, feel the effects of its expenditure which had been so profuse in early life: many striking instances of which I have witnessed. Similar observations apply to long-protracted illness, severe misfortunes, or any other cause which at any period of life in a great degree, and for a considerable length of time, tend to exhaust the excitability of the vital system, although for a certain time the individual may enjoy his usual health after such causes have ceased to operate *.

The organs of the leading power in the vital system, as appears from the facts stated in my paper on the Nature of Death, possess at birth a high degree of excitability, a degree beyond that proportion which constitutes the firmest state of health—the cause, as there pointed out, of many of the most fatal diseases of infancy—which is by the operation of the usual stimulants of life gradually reduced till it bears a due proportion to those stimulants, by which the powers of the constitution are confirmed. At length from their continued operation the fault is a defect not a redundancy of excitability, to which every day necessarily adds, till they can no longer excite the organs on which that power depends; for in every instance the immmediate cause of absolute death, which is very different from what we call death, is the failure of that power †. And here as there are no means in the constitution, as in the case of the organs of the leading power in the sensitive system, of restoring the excitability of its organs, they at length finally cease to be excited. Thus it is that in almost all cases of great longevity we find that there has been little exposure during life to powerful causes of exhaustion of either body or mind, for we have seen that the nervous is immediately under the influence of the sensorial power; and that such instances are most frequent in the colder of the temperate climates, heat, on the one

* See what is said of the excitability of the two systems in my papers on the Nature of Sleep and Death.

† My paper on the Nature of Death. Philosophical Transactions for 1834.

hand, tending to exhaust excitability, and extreme cold, on the other, to render us less capable of excitement.

While considering the laws of excitability it is necessary to bear in mind an essential property of all those agents which are capable of calling it into action, and which has demanded less attention than its great importance in the treatment of disease demands. There is no agent capable of influencing either of the two systems into which the functions of the living animal arrange themselves, whether it be such as makes its chief impression on the mind or body, which is not capable of acting either as a stimulating or directly debilitating power according to the degree in which it is applied. There is none which may not be applied in so small a degree as to act as a stimulant, and in so great a degree as to act as a directly debilitating power. The most depressing passion in a comparatively small degree will excite, the most exciting in an excessive degree directly debilitate; and the same stimulus by which either the nervous or muscular fibre is directly excited, will by its excessive application directly deprive it of power. I know of no exception to this law. All medicines within their stimulant range excite, and unless the excitement exceeds the degree which produces no correspondent depression, (for such a degree of excitement is compatible with the laws of the vital though not with those of the sensitive system*,) it acts as a permanent tonic. All, beyond their stimulant range, act as directly, and although within that range, if of a certain intensity, as indirectly debilitating powers with respect to both systems†.

IT is evident from many facts, stated in my papers on the Nature of Sleep and Death, that each of the foregoing systems is a whole, which cannot be influenced in any one part without a tendency to be affected in all others; a property which perhaps more than any other influences the progress of their deviations from the healthy state; for every part more or less feeling the change effected in any one, if there be any from accidental causes more liable to disease than the rest, this part particularly feels the cause which operates on all; and, as I shall soon have occasion to point out more particularly, is even the means of diverting its effects from every other part. Thus it is that diseases of continuance become complicated, and that an affection, attended with little risk in the part first impressed by the offending cause, often becomes formidable by its secondary effects.

* My paper on the Nature of Sleep in the Philosophical Transactions for 1833.

† See what is said on this subject in my treatise *On the Influence of Minute Doses of Mercury in restoring the Functions of Health*, and my Gulstonian Lectures on the more obscure affections of the Brain, also in the recapitulation at the end of this paper. All my Treatises, to which I have occasion to refer, are more or less founded on the principles here recapitulated; and consequently in them more or less copious references to the facts, on which these principles rest, became necessary. In order to arrive at the conclusions of the present paper, it was necessary to state the whole of those facts with their various bearings, which I have done in as concise a manner as the requisite perspicuity appeared to admit of. In the less familiar parts of the subject, it requires some care to avoid being misunderstood.

The power which operates here, has been termed the sympathy of parts, the effects of which I have considered at length in a treatise on the more obscure diseases of the brain, being the Gulstonian Lectures delivered at the College of Physicians in 1835. I am now, after referring to its more prominent effects, to consider the nature of this function, and the powers on which it immediately depends.

AS it appears from the experiments above referred to that the organs of the sensorial and nervous powers, the leading principles of the two great systems the functions of which comprehend all the functions of life, although both belonging to the brain and spinal marrow, are distinct sets of organs; the one set being confined to a comparatively small portion of these organs, the other distributed through the whole of them, from the uppermost surfaces of the brain and cerebellum to the lowest portion of the spinal marrow; and as numberless observations evince that the immediate cause of sympathy exists in the central organs alone *, it follows that these systems must have different centres of sympathy, that if the different parts of each system sympathize, it cannot be through the same centre †. Now it appears from the phenomena of disease, compared with the results of the experiments just referred to, that each of the centres of these systems is often influenced with so little disturbance to the other, that disease of either system, especially when of a chronic nature, often spreads to distant parts of the system in question, without much affecting the other; a favourable result in the sensitive system, because it is only in proportion as the organs of the vital system are implicated that life is endangered; but in the vital system the most fruitful of all causes of obscurity, and that in diseases of the most formidable nature, to which many have fallen, and still fall a sacrifice; for so ill supplied are many of the vital organs with nerves of sensation, that in them diseases of sympathy often make a fatal progress without the state of the part originally affected having attracted attention, and without its restoration, that of the part secondarily, but more prominently, affected is impossible ‡. Thus also it is,—that is, in consequence of the one system often suffering with little disturbance to the other,—that extreme suffering not unfrequently continues for years without materially impairing the functions of life, the organs of suffering belonging to the sensitive system; while in other instances immediate danger presents itself with so little previous suffering, that even the medical attendant is unprepared for it.

* My Gulstonian Lectures.

† Ibid.

‡ The internal water in the head of children, for example, has, till within the last thirty years, been almost uniformly fatal, having been treated as an original affection of the brain. Dissection having now proved it to be a secondary affection depending on the state of the liver, there are few serious diseases in which the treatment is more uniformly successful, if it has not been allowed to arrive at its last stage. The original affection, which does not betray itself by any prominent symptom, being removed, its consequences yield to the means, which are powerless while it continues to operate. Other affections of the head, certain forms of pulmonary consumption, and many other diseases might be adduced as illustrating the same principles.

The latter evil can only be obviated by a careful study of the laws of sympathy in the vital system, and particularly by ascertaining what organs are most inclined to be affected by what others; for although the function of sympathy is, like other functions, influenced by causes peculiar to the individual, it is in a great degree regulated by principles, which more or less prevail in all*.

From the facts just referred to we easily perceive the cause of the sympathy by which every part of each of the foregoing systems is capable of influencing every other. Each is regulated by a leading principle, and in consequence of this, under an influence by which the affection of any one part tends to affect all others; because as all parts of each system both influence this principle, and are influenced by it, it necessarily follows that all must, through it,—that is, through the central organs of each system, which alone are the immediate organs of its leading principle,—feel the affections of each. Such, together with the laws I am now to consider, is the source of the function to which the term sympathy has been applied, a principle as I have just had occasion to observe, which perhaps more extensively than any other regulates the course of disease.

As each of the preceding systems is formed into a whole by its leading principle, the relations which these systems bear to each other have a similar effect with respect to the whole frame; for the affection of any one of its parts tends more or less, though much less powerfully than in the individual systems, to influence all others. The means by which the relation between the sensitive and vital systems, and consequently the most complicated functions are maintained, we are here to consider; to some of them I have already had occasion to refer.

WE have seen that the nervous power properly so called, the leading power in the vital system, is immediately under the influence of the sensorial power, the leading power in the sensitive system, and constitutes the medium through which all that part of our intercourse with the external world, by which the latter power influences it, is maintained. This therefore is the first bond of connexion to which I shall refer between the sensitive and vital systems. The second is the means by which the organs of both systems are maintained; for, as I have already had occasion to observe, the sensorial has a dependence on the vital system, for the maintenance of its organs, as the vital, we shall find, has a more remote dependence on the sensorial system, for the maintenance of its organs; the connexion thus established between them being increased by both systems equally depending for the maintenance of their organs on the muscular power and the powers of the living blood; both of which are in their turn subjected to the nervous, and the former certainly, and the latter, we have reason to believe, through the nervous, also to the sensorial power.

The sympathy which prevails through all parts of each system also contributes to the influence of these systems themselves on each other; because the state of the

* My Gulstonian Lectures.

parts secondarily affected in consequence of the power of sympathy, more or less influences both systems, all parts being more or less supplied with nerves from both.

But we have sufficient evidence in the phenomena of disease, compared with the results of the experiments referred to, that here, as in the instances just pointed out, the central organs of the sensitive, directly influence those of the vital system. A sympathetic pain it is well known referred to any part will at length produce actual inflammation of the part. Now while the pain alone exists, we know that the derangement, which produces it, is in the central organs alone of the sensitive system, and in no degree in the part to which it is referred; and we also know from the facts which have been stated that there is no channel through which this derangement can influence either the nerves or vessels of the part, but through the central organs of the vital system.

When the affection of the nerves or vessels of the part is the original disease, it influences the central organs of both systems by the actual disease of the part; but in the former case there is no other channel of communication than that just referred to. The central organs of the sensitive, having no power over either the nerves or vessels, can only influence them through the central organs of the vital system. Thus arises a double bond of connexion between the two systems, the central organs of the sensitive system directly influencing those of the vital system, and the nerves of the sensitive system being necessarily influenced by all deviations from a state of health in whatever part, for all parts may be affected through the central organs of the vital system, the degree to which the effect in the sensitive system takes place being proportioned to that in which the part is supplied with nerves of sensation. As the central organs of the sensitive, directly influence those of the vital system; the latter, through the extremities of the different nerves with which the two sets of organs are associated, influence the former. Hence we have just seen the fatal obscurity of many diseases of those vital organs, which are ill supplied with this class of nerves; and as the more chronic the disease, the less it disturbs the sensitive nerves, it is in the more chronic cases that the obscurity is greatest, and consequently attended with the greatest risk.

Different parts of the central organs of the sensitive system correspond to different parts of the general frame. This is perhaps sufficiently proved by our being enabled by experience to refer our sensations to the seat of the cause which excites them; but in many of the inferior animals, where both the brain and spinal marrow partake of the organs of the sensorial power, it may be proved by direct experiment, because after the removal of the brain we find the sensorial power lost only in those parts which derive their nerves from that organ.

But how comes it that the central organs of the vital system also have relation to certain parts of the general frame, the nerves associated with these organs conveying, as appears from what has been said, their combined influence, which is bestowed alike on all vital organs?

It is a law of the animal economy, amply illustrated by the phenomena of disease, that when an impression influencing the system generally is, by previous debility or any other cause, directed to a particular part, its operation is diverted from all others. Now it appears from a thousand phenomena that the suffering of the sensitive system, referred to any particular part, is sufficient, under certain circumstances, in consequence of the influence of the central organs of the sensitive, over those of the vital system, to direct to it the effects of derangement excited in the latter. Thus even a diseased organ will often regain its healthy state, when the disease has spread to another, particularly if in the latter, it takes deeper root, if I may use the expression. It is a daily occurrence for a disease of function to be finally removed by a disease of structure being established in another organ. Hence the good effects of artificially exciting disease in external parts to relieve those more immediately essential to life; and the still more salutary effect, when the laws of our frame themselves produce the same effect, because here it is the uninfluenced result of those laws, whereas in the former case their tendency is constrained by artificial means. Thus for example it is that the inflammation of a gouty joint or other external disease often relieves the derangement of a vital organ, and that artificially repelling this effort of the constitution to save a vital part, has so often proved fatal.

On the facts that the central organs of the vital system directly influence the functions both of the vital nerves and of the vessels of every part, while those of the sensitive system have no direct influence on either, many of the phenomena of disease depend; because it is only in proportion as these nerves and the vessels of the part are influenced, that any disease of the part itself exists, and consequently that there is any tendency to derangement either of function or structure in the part; of function alone if the nerves alone are affected, of structure also as soon as the vessels partake of the disease. Hence it is that the tendency to change of structure, except where it takes place by imperceptible degrees, is, *cæteris paribus*, always proportioned to an inflammatory tendency which may be detected in the part, this tendency being the first indication that the vessels partake of the disease; and hence the importance of carefully watching and checking its approach, if the part be one essential to life, in all cases of deranged function of, or even of painful sensations referred to, particular parts.

EXTENSIVE as the foregoing relations of the vital and sensitive systems are, they are not the only ones. To determine the whole of them it is necessary to review the functions of the more perfect animals, and in particular correctly to ascertain the line of distinction between the functions of the two systems; in order to determine whether there be any beside those just pointed out in which they cooperate, and which consequently contribute to their dependence on each other.

I made many experiments with a view to draw the line of distinction between the vital and sensitive functions; and that the result might be the more certain, the attempt was made by two sets of experiments, conducted on different principles. By

the one I attempted to ascertain what functions remain when the sensorial powers are withdrawn; by the other, what functions fail with the failure of the nervous powers; and the correspondence of the results of these sets of experiments tends to confirm the inferences from both*.

Much confusion had arisen from physiologists having neglected to ascertain this line. M. LE GALLOIS, one of the most acute, soon found his difficulties from this cause such, that he was obliged to confess himself unable to proceed, and leave to his successors the task of removing them. He had adduced sufficient proof of the spinal marrow, to which the nerves of respiration belong, being capable of its functions independently of the brain; yet on the removal of a part of the brain, the medulla oblongata, respiration ceases. This difficulty he acknowledges he sees no means of removing, calling it "un des grands mystères de la puissance nerveuse, mystère qui sera devoilé tôt ou tard, et dont la découverte jettera la plus vive lumière sur le mechanisme des fonctions de cette merveilleuse puissance."

If the preceding facts be kept in view, it is evident without much consideration that none of the functions of the sensitive have any other dependence on the powers of the vital system, but for the due structure and wellbeing of their organs. The nature of the functions of the vital system here requires more consideration. They include respiration; circulation; those processes by which the secreted fluids are formed; those, namely the more immediately assimilating processes, by which our food is converted into the various organs of our bodies, and such parts of them as have become unfit for the purposes of life are separated and expelled, for all are in a state of change; and those by which the due temperature is maintained.

Does the sensitive cooperate with the vital system in any of these functions?

From the line of distinction, determined by the experiments just referred to, it appears that in one of them only is there such a cooperation.

I have in the last of my papers published in the Philosophical Transactions for 1829 considered at length the nature of respiration, and have, as far as I am capable of judging, adduced such facts as prove that the muscles employed in this function are, in the full sense of the word, muscles of voluntary motion. The first act in respiration is the impression made on the sensorium, the sensation excited by the want of fresh air in the lungs. We are enabled to supply it and remove the uneasiness, by exciting, through the nervous system properly so called, certain muscles subject to the will.

Respiration thus depending on the combined operation of both systems, is as effectually destroyed by a failure of the sensation which makes us will to inspire, as by that of the nervous or muscular power by which the will effects its object. Thus the difficulty of M. LE GALLOIS disappears. It is true that the spinal marrow and its nerves are capable of their functions independently of the brain, and that the nerves employed in respiration are supplied by the spinal marrow, but in this function it is an act of

* *Inquiry into the Laws of the Vital Functions*, Part II.

volition which excites them. They are quiescent till this act takes place. Hence it is that respiration ceases on the removal of the medulla oblongata, because by the removal of this part of the brain the power of sensation in all parts below the head and consequently of volition, as far as relates to those parts, is destroyed. Hence also the fact, above referred to, that the vital has a remote dependence on the sensitive system for the maintenance of its organs. If the muscles of respiration were not in the strictest sense muscles of voluntary motion, our powers of volition would in an essential respect be imperfect; for the due regulation of their action is essential in the formation of articulate sounds, the chief means by which our sensorial powers are enabled to influence those of other sentient beings.

In the papers on the Nature of Sleep and Death, published in the Philosophical Transactions for 1833 and 1834, I have pointed out how much the functions of the more perfect animal are influenced by this peculiarity of respiration, the only vital function, properly so called, in which the sensorial power cooperates; a circumstance which more generally perhaps than any other, which is equally of a local nature, influences the phenomena both of health and disease. In this function therefore we find a powerful bond of connexion between the sensitive and vital systems, and one, as appears from the papers just referred to, of the most extensive operation.

SUCH are the means by which the frame of the more perfect animal is formed into a whole, and the function of sympathy and its other more complicated functions above enumerated effected. A powerful connexion is established among all parts of each of the systems into which the functions arrange themselves, depending on each being regulated by a leading power which influences every part of the system to which it belongs, and in its turn is influenced by every part of it: and these systems themselves are intimately related in consequence of the nervous, the leading power in the vital system, by means of the control which the sensorial power exercises over it, being employed in the accomplishment of many of the sensitive functions, and the sensorial power, the leading power in the sensitive system, in one of the most important of the vital functions; by both systems not only depending for the maintenance of their organs on the same powers, but more or less directly on each other; by the powers common to both systems being under the influence of the leading principles of both; and by all affections of whatever part, whether original or sympathetic, necessarily influencing both its sensitive and vital nerves, and consequently the central organs of the system to which they belong.

FROM the whole of the facts referred to in the preceding paper, the great outline of the laws which regulate the functions of the more perfect animal is derived. The parts of which it consists, from the complicated nature of the subject, being very numerous, it is necessary, in order to place it in a clear point of view, concisely to recapitulate them; and as in the preceding paper, I commenced with the more

simple, and was, by their intimate connexion with the more complicated powers, led to them; I shall in the recapitulation, that they may be viewed in both directions, begin with the more complicated, which by the same means will lead us to the more simple powers.

BESIDE the mechanical powers, of which the living animal evidently partakes in common with inanimate nature, it possesses, we have seen, four distinct powers, apparently peculiar to itself, having no direct dependence on each other, but each depending on the other three, for the maintenance of its organs; the sensorial, the nervous and the muscular powers, and the powers of the living blood.

By these powers are maintained the two systems into which the various functions arrange themselves, the vital and sensitive systems, the object of the one being the maintenance of our bodies, of the other, our intercourse with the external world.

THE organs of the sensorial power in man have their seat in the brain. They can be excited by no other means than the influence conveyed by the nerves of sensation, in the most extended sense of the expression, in every instance called into operation by impressions made on their extremities by agents which belong to inanimate nature, either existing within our own bodies, or making their impression from without; and, on the other hand, there are no means by which the sensorial organs can influence those agents but through the intervention of the powers of the nervous system properly so called. The nature of the sensorial power, we have seen, admits of no direct intercourse between its organs and the agents of inanimate nature, because it operates by properties, which have nothing in common with those of such agents; and as it can only receive impressions from the external world through the nerves of sensation, with which it is associated, it can only impress the agents of that world through the muscles of voluntary motion, excited by the nerves associated with them. Thus it is necessary, as we have by direct experiment found to be the case, that the organs of the nervous system should be placed under the control of the sensorial power. Through the same channel, we have seen, this power also, in some of their functions, controls the muscles of involuntary motion; and we have reason to believe, although the point has not been ascertained by direct experiment, all the powers of the living blood. And such, as appears from facts above referred to, is its influence on the nervous, and through it, on the muscular power, and we have reason to believe on the powers of the living blood, that it can not only excite, but impair and instantly destroy all these powers, according to the nature and power of the causes which influence its organs.

The circumstance of the muscular, as appears from facts above referred to, being the moving power of the blood in the vessels as well as the heart, greatly extends the influence of those powers which control it, namely the nervous power properly so called, and the sensorial power acting through it.

The only respects in which the sensorial power is related to the subject of this

paper, are in the impressions it receives from the nerves of sensation, and the functions in which it cooperates with the nervous and muscular powers. Sensation and volition are the only sensorial powers employed in the maintenance of life.

While the organs of the sensorial power are thus capable of more or less directly influencing all the other organs of the living animal; they more or less feel in their turn, through the medium of the nerves of sensation, which, we have seen, convey an influence of wholly a different nature from that conveyed by the nerves associated with the organs of the nervous power properly so called, all changes effected in any part of our frame. By these means, this power constitutes the leading principle in the sensitive system, of which its organs form the central parts.

THE organs of the nervous power properly so called, have their seat equally in the brain and spinal marrow, and throughout all parts of them; and are excited, on the one hand, by the direct influence of the sensorial power, and on the other, by agents influencing the vital organs throughout every part of the frame; all of which, as in the case of the impressions made on the nerves of sensation, whether existing in our own bodies or making their impression from without, are agents of inanimate nature.

The immediate functions of the unaided nervous power are the excitement of the muscles of voluntary motion in all their functions, of the muscles of involuntary motion in some of their functions; and the immediate functions of this power in cooperation with the muscular power and the powers of the living blood, all the powers of both of which are directly subjected to its influence, are the formation of the secreted fluids, the maintenance of animal temperature and the various more immediately assimilating functions,—namely, the functions by which, on the one hand, our food is converted into our various organs, and, on the other, those parts of them which have become useless, are separated and expelled,—which renders it necessary that the muscles of involuntary motion as far as they cooperate in these functions, which with few exceptions include the whole of these muscles, should, as we have seen from direct experiment is the case, be under the immediate influence of the nervous power.

Neither the brain nor spinal marrow in the functions of the vital system acts through the other of these organs, as the brain is found to do through the spinal marrow in many of those of the sensitive system; each directly influencing every part.

The direct influence of the nervous power, it appears from what has been said, extends to all the functions of the system with the exception of those of the sensorial power, which it only influences through other functions. It directly influences, and is directly influenced by, all the vital functions properly so called, and hence constitutes the leading principle of the system to which they belong, therefore termed the vital system, of which its organs form the central parts.

THE circumstance of each of the foregoing systems being under the influence of a

leading power, which is both capable of influencing and being influenced by every part of it, is the cause of that powerful sympathy which exists among all its parts, and which we have seen often essentially influences either system with but little disturbance to the other, on which many of the most important phenomena of disease depend.

THE muscular power, which has its seat we have seen in the muscular fibre itself, and the powers of the living blood, which have their seat in the blood itself, perform subordinate parts. They are equally employed in both systems for the maintenance of their organs. The latter supplies the materials endowed with the principle of life on which the nervous power operates in the formation of the secreted fluids, the maintenance of animal temperature and the various more immediate functions of assimilation; while the former, to which the vessels as well as the heart owe their power, supplies the means by which these materials are duly exposed to the operation of the nervous power, by which their necessary changes are effected; that is, to the influence of the extremities of the nerves, by which the nervous power operates in all these functions, as well as in the excitement of the muscles; for as the brain and spinal marrow, as we have seen proved by direct experiment, are the only parts of the nervous system employed in preparing the nervous influence; the minute extremities of the nerves are the only immediate organs of its functions; as the extreme parts of the sanguiferous system, the capillary vessels, are the organs by means of which the blood is immediately exposed to its influence.

That the capillary vessels may be, as little as possible, influenced by adventitious causes in functions of such importance in the animal economy, we find on the one hand, as appears from experiments above referred to, that the motion of their blood depends wholly on their own powers, the larger arteries which depend for their supply of blood on the heart, being only the reservoirs from which they draw their supply; and that, on the other, they are not controlled by the nervous influence through the medium of the heart, but receive this influence directly from its source: and so correct are these positions, that even the removal of the heart, if effected without considerable loss of blood, produces no immediate effect either on the action of the capillaries, or the control which the nervous power exercises over them.

SUCH are the individual powers of the living animal, their seat, the relation they bear to each other, and the manner in which their several functions are effected.

BUT the most complicated functions, it appears from what has been said, depend on the relations which subsist between the two systems themselves, into which the functions of all these powers are arranged.

They are related to each other, we have seen, by the nervous, the leading power in the vital system, in consequence of the control exercised over it by the sensorial, the

leading power in the sensitive system, being employed in many of the functions of the latter; by the sensorial being employed in one of the most important of the vital functions, this peculiarity of respiration, for in no other of those functions is there any such cooperation, extensively influencing the phenomena both of health and disease; by both systems depending for the maintenance of their organs on the same powers, and more or less directly on each other; by the powers common to both systems, the muscular power and the powers of the living blood, being under the influence of the leading powers of both; and by all affections of whatever part necessarily influencing both its sensitive and vital nerves, and consequently the leading powers of both systems.

AS the various parts of each system are formed into a whole by all parts of each influencing and being influenced by its leading principle, so all parts of the animal body are formed into a whole, no part of which can be affected without tending more or less to affect all others, by the means just enumerated, by which these systems influence each other. Such are the foundations on which the laws of sympathy depend, a principle which, as I have endeavoured in a cursory way to point out, more than any other, influences the course of all deviations from a state of health.

THE functions of all the powers of the living animal, we have seen, are mediately or immediately excited by agents belonging to inanimate nature. Our organs are composed of the same materials with the external world, and can only be immediately impressed by agents of their own nature. It is true that the sensorial functions are the results of one vital part acting on another, the sensitive nerves on the immediate organs of the sensorial power; but the impression these nerves convey is in every instance received from the agents of inanimate nature. Here both the agent and the organs impressed are of the same general nature, being composed of similar materials, with our other organs. The peculiarity of the results depends on vital properties alone being employed in their production, whereas in all other functions of the living animal, the vital properties of the organ cooperate with the properties of the inanimate materials of which it is composed. Hence it is that its functions admit of being immediately excited by the agents of inanimate nature, which, having no properties in common with the only properties employed in the sensorial functions, cannot directly cooperate in their production.

Every agent capable of exciting any of the functions of the living animal, we have seen, acts as a stimulant or directly debilitating power, according to the degree in which it is applied. In the sensitive system their stimulant effect is always followed by a proportional exhaustion of excitability; in the vital system, only when the excitement exceeds a certain limit. I speak of a sensible exhaustion, an exhaustion beyond that produced by the usual stimulants of life, which, in the vital system, is too gradual to be perceived, and as far as relates to any particular stimulant employed

within such limit, is so trifling that it may be safely overlooked. Hence it is that the vital system appears to possess an excitability which is not exhausted by stimulants except when applied in excess. It is essential, we have seen, in the treatment of disease to keep in view these properties of all agents capable of influencing the functions of life, that we may, as much as the nature of the case admits of, keep within the stimulant range of our remedies; and within that range, as far as possible, avoid the degree of excitement which produces sensible exhaustion of the vital organs.

WITH respect to the nature of the powers of the living animal which we have been considering, the sensorial and muscular powers and the powers peculiar to living blood we have found belong to the living animal alone, all their peculiar properties being the properties of life. The functions of life may be divided into two classes, those which are effected by the properties of this principle alone, and those, by far the more numerous class, which result from the cooperation of these properties, with those of the principles which operate in inanimate nature. The nervous power we have found to be a modification of one of the latter principles, because it can exist in other textures than those to which it belongs in the living animal, and we can substitute for it one of those principles without disturbing the functions of life.

Late discoveries have been gradually evincing how far more extensive, than was supposed, even a few years ago, is the dominion of Electricity. Magnetism, chemical affinity and (I believe, from the facts stated in the foregoing paper, it will be impossible to avoid the conclusion) the nervous influence, the leading power in the vital functions of the animal frame properly so called, appear all of them to be modifications of this apparently universal agent; for I may add, we have already some glimpses of its still more extensive dominion.

IN the preceding paper my objects have been to review the whole of the functions of the more perfect animal, to ascertain the nature of the powers on which they depend, the seat of each of these powers, the manner in which they are employed in effecting their several functions, and the manner in which they are associated in producing their more complicated results. Nothing in any part of the subject has been taken for granted, no position having been advanced without a reference to the observations or experiments on which it is founded.

I have here for the first time made an attempt which could not be done till all the facts on the subject had been ascertained, to point out the manner in which the different powers of the living animal influence each other, and thus conduce to their more complicated results; by which, being enabled to analyse these results, it might easily, were this the proper place, be shown, that we better see the operation of its different powers in the various deviations from a state of health, and can, under certain circumstances, better regulate the means of obviating them.