AN

EXPOSITION

OF

THE NATURAL SYSTEM

OF THE

NERVES

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THE HUMAN BODY.

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WITH A REPUBLICATION OF

THE PAPERS DELIVERED TO THE ROYAL SOCIETY,
ON THE SUBJECT OF THE NERVES.

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PREFACE.

In the Introduction to these papers the Author has given the reasons which his friends have urged for this publication; but he cannot let this opportunity pass without making an apology for its imperfections.

It was not his original intention to publish in this manner, but to continue to give distinct dissertations, under the auspices of the Royal Society, and afterwards to publish engravings of the nervous system.

By this slower process, the subjects might have been taken up successively, and might have been more thoroughly investigated; but it has become apparent to every body interested in anatomical inquiries, that a systematic attempt has been made, not only to anticipate the future subjects, but to assume whatever merit may belong to these discussions. By thus snatching at parts, without comprehending the whole system, a wrong notion has been conveyed about it; matters of fact, and conclusions, drawn from diligent inquiry, are mixed up with absurd fancies, and a false colour is given to the whole.

The obvious remedy is the publication of the system; but the Author regrets the necessity of doing this, as it was his wish not to place it before the public in an imperfect state.

The reader must see that many of the subjects are capable of farther illustration, and that the system may be strengthened by future inquiry. Even during the present season, in delivering his lectures to his class, the Author has found new facts and suggestions offering themselves, which he could have wished had been incorporated in the present volume.

Soho Square,
Nov. 12. 1824.

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Soho Square,
Nov. 12, 1834

ERRATA.

In Plate I. there is an omission of one of the cervical nerves.

The reader is requested to correct the following with his pen : —

Page 44. line 7. read "seven" for "six."

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A DESIRE having been very generally expressed to see a connected view of the new system of the nerves, the following account has been drawn up for this purpose. Something of this kind has indeed become necessary in addition to the papers published by me in the Philosophical Transactions: for although those dissertations explain some of the remarkable facts brought out in the course of the investigation, they do not convey an idea of the system as I have conceived it; nor display its chief excellence, which is its simplicity, and the order which by means of it, has been introduced into the demonstration of the nerves.

My conceptions of this matter arose by inference from the anatomical structure; so that the few experiments which have been made, were directed only to the verification of the fundamental principles on which the system is founded.

In France, where an attempt has been made to deprive me of the originality of these discoveries, experiments without number and without mercy have been made on living animals; not under the direction of anatomical knowledge, or the guidance of just induction, but conducted with cruelty and indifference, in hope to catch at some of the accidental facts of a system, which, it is evident, the experimenters did not fully comprehend.

When a subject like this is investigated according to the true order and just philosophy, and the facts of anatomy strictly attended to, every experiment is decisive; and the truth comes out so clear and simple, that nothing can be more satisfactory either to the man of science or to the general enquirer.

I trust that it is altogether owing to the want of a short and clear exposition of this subject, that so little has been said of a system which introduces the student with remarkable ease to a knowledge of the nerves; and which has been crowned with the discovery of so many facts important to the knowledge of the animal economy, and to the principles of the healing art.

The view which I have taken of the nerves, has not been the result of hasty and premature conjecture, but of patient investigation. From the first year of my delivering lectures, my demonstrations of the brain were given in a manner not then common; and to this peculiarity in the manner in which I looked on the connections of the brain, I trace the origin of opinions different from those hitherto entertained. By the time I began to lecture in Windmill Street, I was enabled to follow in my demonstrations of the nerves an arrangement which has given a new interest to the subject, and which by imperceptible degrees and improvements from year to year, during every succeeding course of demonstration, has at length developed the comprehensive system which I have now to present to the reader.

The steps by which I have cautiously

advanced, have been observed only by my older and more diligent pupils; who, becoming interested in the subject, have returned, during successive years, when this subject was under consideration, to hear how I continued to prosecute it. They have seen the system gradually developed, and have heard me announcing the desiderata as the enquiry proceeded, and explaining the difficulties; and they have seen how the points which were in one season the most obscure have, by diligent investigation, become those of the very highest interest in succeeding courses.

In the first paper delivered to the Royal Society on this subject, I have expressed an opinion, feebly in comparison with what I had it in my power to do when the dissection of the nerves lay before me, namely, that the subject of the nerves was left by anatomists in extraordinary confusion. The reader must have felt something like dismay in contemplating the full display of the nerves of the face, neck, and chest; and this feeling is not less strong in turning to the labours of Scarpa or of Walther, and surveying their beautiful plates of the nerves of the thorax. It is natural to ask, whence arises this extraordinary confusion? Why nerves run into knots? Why nerves come from different sources to combine together? And why organs are supplied with more than one cord of connection to the brain? why have some two, some five, and some only one?

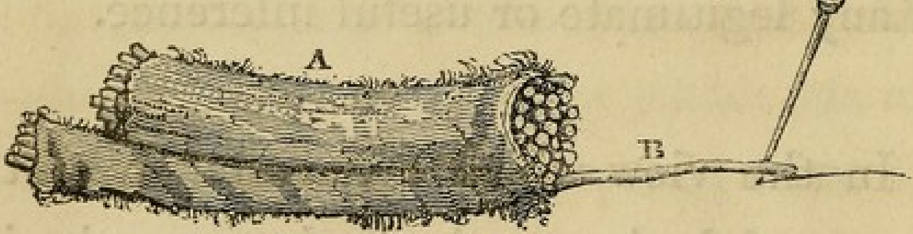
In the course of these papers I have shown, that the great error which has misled anatomists in their conceptions concerning the nerves has consisted in following, though with some license, the old hypothesis that the nerves receive their influence from the brain and confer it on remote parts of the body, and that they are endowed with the same powers. For whether we look upon the intricacy of the parts on dissection, or attempt to unravel the mystery of sensation, and voluntary and involuntary motion, performed by a single nerve, there is a complete discrepancy betwixt the fact and the hypothesis, and the subject is left in an unsatisfactory and humiliating state of uncertainty. The student is dismayed with his task; the skill of the anatomist is baffled; and the philosopher, if he should approach this subject, is left without a single fact relating to the nerves, which can serve as the foundation of any legitimate or useful inference.

In the view which I have taken of the nerves of the human body there are, beside the nerves of vision, smell, and hearing, four

 taste

systems combined into a whole. Nerves entirely different in function extend through the frame; those of sensation ; those of voluntary motion ; those of respiratorymotion ; and lastly, nerves which from their being deficient in the qualities that distinguish the three others, seem to unite the body into a whole, in the performance of the functions of nutrition, growth, and decay, and whatever is directly necessary to animal existence.

These nerves are sometimes separate ; sometimes bound together ; but they do not, in any case, interfere with or partake of each other's influence.



The figure represents a nerve, consisting of distinct filaments.
A the nerve ; B one of the threads dissected out.

If we take up a nerve to examine it, we find that it consists of distinct filaments; but there is nothing in these filaments to distinguish them from each other, or to declare their offices. One filament may be for the purpose of sensation; another for muscular motion; a third for combining the muscles in the act of respiration. But the subserviency of any of all these filaments to its proper office must be discovered by following it out, and observing its relations, and especially its origin in the brain and spinal marrow. In their substance there is nothing particular. They all seem equally to contain a soft pulpy matter enveloped in cellular membrane, and so surrounded with a tube of this membrane as to present a continuous track of pulpy nervous matter, from the nearest extremity in the brain to the extremity which ends in a muscle or in the skin.

Previous to the observations which I have made, such a nerve as I have described was supposed to have all its threads alike; they were supposed to be branches from the same root, and all capable of exciting a muscle or conveying a sensation.

The key to the system will be found in the simple proposition, that each filament or track of nervous matter has its peculiar endowment, independently of the others which are bound up along with it; and that it continues to have the same endowment throughout its whole length. If we select a filament of a nerve, (for example, one of those in the compound nerve represented above,) and if its office be to convey sensation, that power shall belong to it in all its course wherever it can be traced: and wherever, in the whole course of that filament, whether it be in the foot, leg, thigh, spine, or brain, it may be bruised, or pricked, or injured in any way, sensation and not motion will result; and the perception arising from the impression will be referred to that part of the skin where the remote extremity of the filament is distributed.

As the matter of the nerve is every where the same, and the apparent difference is only in the manner in which the fine cellular membrane forms the envelope, (it being soft where the nerve is protected, hard and cordlike where it is exposed or subject to pressure;) I have been desirous of having some term or terms which might be applicable to the same track of matter through its different stages, whether traced in one direction or the other.

Where certain whitish streaks of nervous matter are discoverable in the substance of the brain, we may still use the term *Tractus* as being already an anatomical term.

Where, in any part, the line of a nerve is not merely discoverable by its colour, or the direction of its texture, but when it is raised, and exhibits an external convexity in form of a cord, the term *Column* or *Rod* may be used.

Where they emerge in distinct threads, *Funiculi* has seemed to me a proper term; and where these *funiculi* are projected in combination, I use the word *Fascis.* Although we must keep the term *Nerve*, yet it is, as we may say, an abused term. Let us only distinguish betwixt a simple and a compound nerve. A simple nerve is where the threads or funiculi which form its root arise in a line or sequence from the brain or spinal marrow. A compound nerve is where the threads forming the roots arise in double rows, and each row from a different column or track of nervous matter; for example, the Ninth Nerve is simple; a Spinal Nerve is compound.

A Nerve, then, is a cord composed of nervous matter and cellular substance; the nervous matter is in distinct funiculi, and these funiculi are bound together in their course to the point of distribution and may possess properties quite dissimilar.

If we were successfully to trace a nervous cord, (we shall suppose from a muscle of the fore-arm,) it would be found a simple filament, thread, or funiculus. We should then trace it into a compound nerve; perhaps the ulnar nerve; which we call compound, because there are in it filaments of motion and filaments of sensation bound together. At the root of the axillary nerve we should trace it into the composition of a fascis, where it forms the anterior root of a spinal nerve. Being further traced, it would merge in the anterior column of the spinal marrow; and traced into the base of the brain, it might be followed as a *tractus*, a streak of matter distinguishable from the surrounding substance, until it was seen to disperse and lose itself in the cineritious matter of the cerebrum. In all this extent, however combined or bound up, it constitutes one organ, and ministers to one function the direction of the activity of a muscle of the hand or finger. Even in this respect its operation is not perfectly simple, for while it excites the muscle to change its state, which we call its state of contraction or of relaxation, it also conveys to the sensorium a sense of the condition of that muscle.*

And so if we trace other fasciculi or, rather filaments, whether they be for the purpose

* This, it would be easy to prove, is a very important consideration in studying the organs of the senses.

of sensation or of motion, each retains its office from one extremity to the other; nor is there any communication betwixt them, or any interchange of powers, further than that a minute filament may be found combined with filaments of a different kind, affording a new property to the nerve thus constituted.

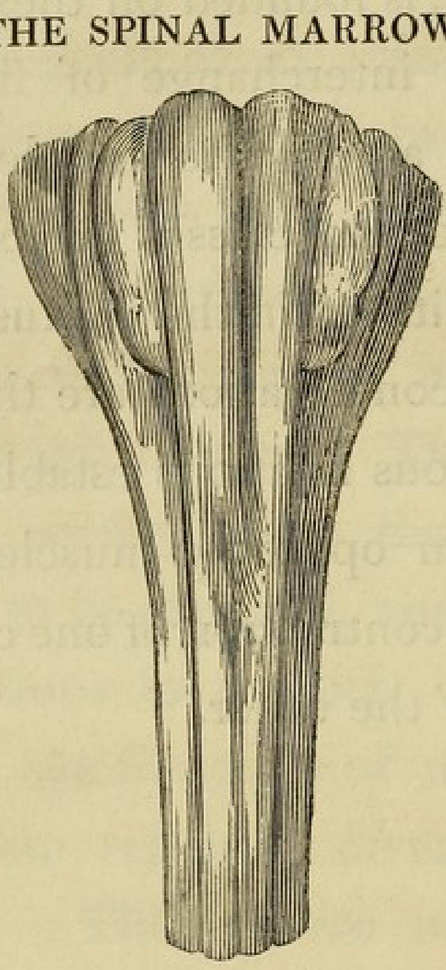
THE CAUSE OF THE COMPLEXITY OF NERVES.

It is the chief purpose of the papers which are here republished, to explain the cause of the seeming intricacy of the nerves of the face, neck, and thorax; but independently of the complexity arising from the causes afterwards to be explained, there are these: — It will be readily understood that some degree of irregularity in the distribution of nerves, must arise from their being compound nerves; but the principal cause is the necessity of arranging and combining a great many muscles in their different offices. Wherever we trace nerves of motion we find that, before entering the muscles, they interchange branches, and form an intricate mass of nerves, or what is termed a *plexus*. This plexus is intricate in proportion to the number of the muscles to be supplied, and the variety of combinations into which the muscles enter, while the filaments of nerves which go to the skin regularly diverge to their destination. The nerves on the face, and those on the side of the neck, form plexus; but the grand plexus are near the origins of the nerves of the upper and lower extremity. And from the fin of a fish to the arm of a man the plexus increases in complexity in proportion to the variety or extent of motions to be performed in the extremity.

The explanation of a plexus which I

have offered, is founded on these facts; viz. that by the interchange of filaments the combination among the muscles is formed: not only are the classes of extensors and flexors constituted in the plexus, but all the varieties of combinations are there formed, and the curious relations established which exist between opposing muscles, or rather between the contraction of one class and the relaxation of the other.

THE SPINAL MARROW.*



In this view of the nerves the internal and radical distinctions are more insisted upon, than that enumeration of their origin and description of their devious course through the body which have hitherto served

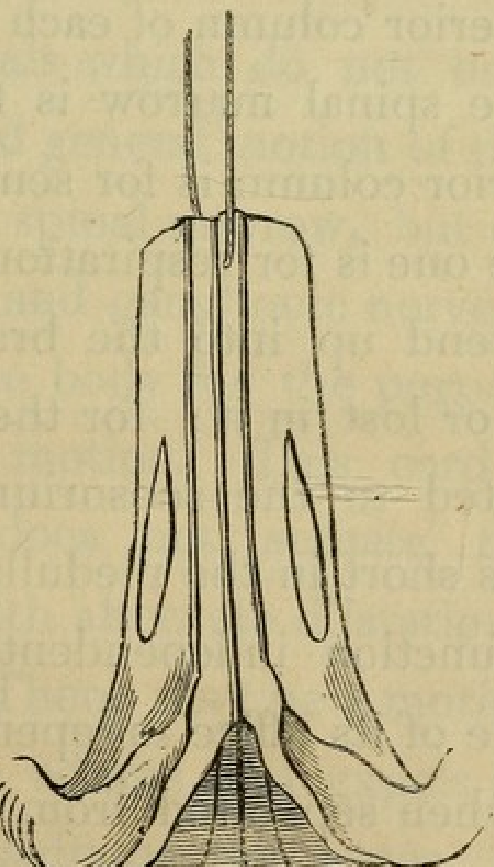
* I have represented above, in a general way, the columnar appearance of the spinal marrow at its upper part; that superior extremity, which, being traced out of the base of the brain, is called *medulla oblongata.*

only to confound the enquirer. We must, therefore, begin the description of the system with that of the spinal marrow. It is by a right arrangement of matters which are familiar, and by attention to a few remarkable and prominent facts, that the groundwork of this system will be best understood.

The spinal marrow is peculiar to the vertebral animals. It will suffice for superficial observers to say, that it must be so, because the spine is necessary to conceal and protect the marrow: but there is much more than this in the established relationship; the spine formed by vertebræ is necessary to such a constitution of the thorax as shall be capable of the motion of respiration; and the spinal marrow is equally necessary to that form and distribution of the nervous system which is required for associating and combining the muscles of respiration. Without the machinery of the spine and ribs the thorax and abdomen could not rise and fall in respiration; and without the spinal marrow that arrangement of nerves would be wanting which is necessary to regulate the motions of the trunk in respiration. Thus the spinal marrow, the spine and ribs, and the muscles of respiration, are essential to each other; as constituting the several parts of a grand design subservient to respiration.

Different columns of nervous matter combine to form the spinal marrow. Each lateral portion of the spinal marrow consists of three tracks or columns; one for voluntary motion, one for sensation, and one for the act of respiration. So that the spinal marrow comprehends in all six rods, intimately bound together, but distinct in office; and the capital of this compound column is the *medulla oblongata*.

These six columns of the spinal marrow are discoverable on looking to the fore part of that body; but no doubt these grander columns contain within them subdivisions. Thus, if we lift up the medulla spinalis from the cerebellum, and look to it on the back part, we shall see more numerous cords, the offices of which will one day be discovered.



The medulla oblon gata, raised by a thread, so as to expose the posterior surface.

This view of the constitution of the spinal marrow led me to institute experiments, which were followed by the discovery of the distinct functions performed by the several roots of the spinal nerves; but without stating these experiments or their results, we shall proceed with the general view.

The anterior column of each lateral division of the spinal marrow is for motion; the posterior column is for sensation; and the middle one is for respiration. The two former extend up into the brain, and are dispersed or lost in it; for their functions stand related to the sensorium: but the latter stops short in the medulla oblongata, being in function independent of reason, and capable of its office independent of the brain, or when separated from it.

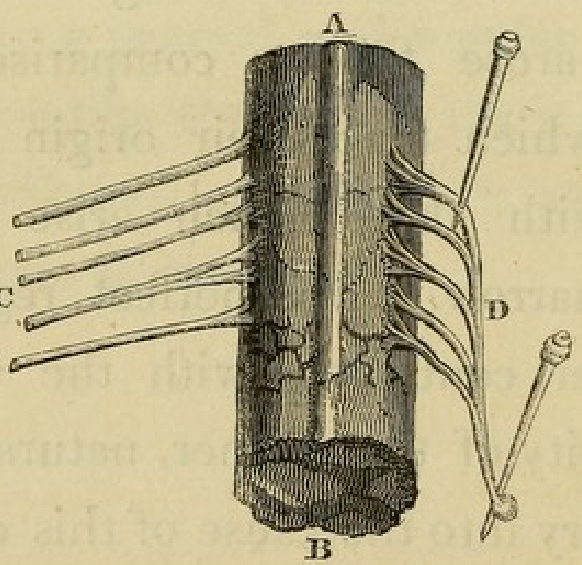
It is the introduction of the middle column of the three, viz. that for respiration, which constitutes the spinal marrow, as distinct from the long central nerve of the animals without vertebræ, and which is attended with the necessity for that form of the trunk which admits of the respiratory motions.

In animals which do not breathe by a uniform and general motion of their bodies, there is no spinal marrow, but only a long compound and ganglionic nerve, extending through the body for the purpose of sensation and motion. This cord in those creatures does not actuate the animal machine with alternate dilatation and contraction. There may be a motion of some part which admits and expels air from a cavity, or agitates the water, and which motion is subservient to oxygenation of the blood; and there may be a nerve supplied to that apparatus with sensibility and power suited to the function thus to be performed, and resembling our par vagum in office; but there is no regular and corresponding distribution of a respiratory system of nerves to both sides of the body, and no arrangement of bones and muscles, for a general and regular motion of the frame like that which takes place in vertebral animals, and which is necessary to their mode of existence.

OF THE NERVES WHICH ARISE FROM THE SPINAL MARROW.—COMPARISON WITH THE NERVES OF THE ENCEPHALON.

The first conception which I entertained of the true arrangement of the nerves, arose from a comparison of the nerves which take their origin from the brain, with those which arise from the spinal marrow. The perfect regularity of the latter, contrasted with the very great irregularity of the former, naturally led to an enquiry into the cause of this difference. I said, if the endowment of a nerve depend on the relation of its roots to the columns of the spinal marrow and base of the brain, then must the observation of their roots indicate to us their true distinctions and their different uses.

The spinal nerves are perfectly regular in origin and distribution, and are thirty on each side.* Each nerve has two distinct series of roots coming out in packets or fasces, one from the posterior column, and one from the anterior column, of the spinal marrow.



A B the spinal marrow seen laterally ; C the posterior roots of a spinal nerve ; D the anterior roots of the same nerve pinned out.

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* The tenth nerve of the head, as enumerated by Willis, and called suboccipital from its situation, is in

The posterior fascis is formed of funiculi, which come out with remarkable abruptness from the column; and their roots form a very regular row or series along the sides of the spinal marrow. They seem at once to burst out from the confinement of the arachnoid coat. These funiculi, converging towards the foramen of the sheath of the spinal marrow, and being collected together, form a ganglion. This ganglion is not seen within the sheath of the spinal marrow; its seat is in the part where the fascis is surrounded and united to the sheath, and just before this root of the nerve joins the anterior one to constitute a spinal nerve.

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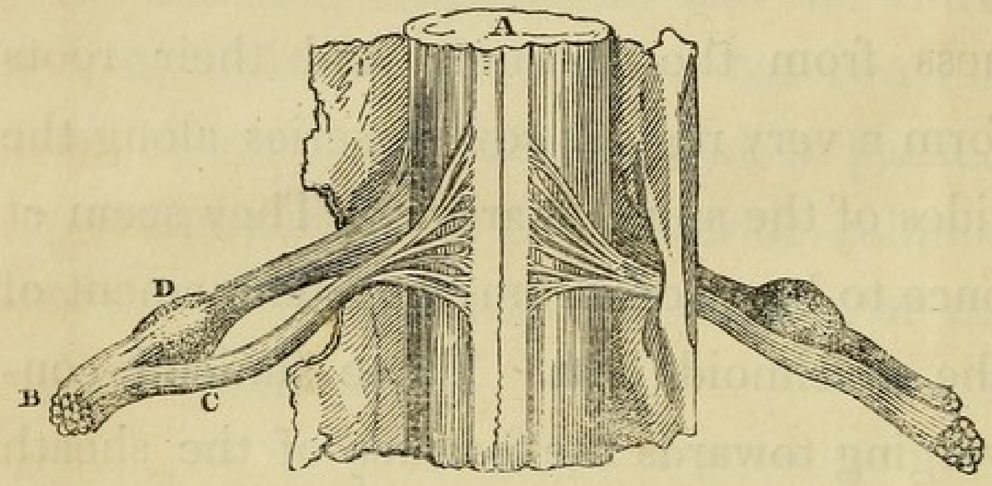
constitution a spinal nerve; *i. e.* it has a double root or ganglion on its posterior root, and its distribution is similar to the spinal nerves, quite unlike those of the encephalon.



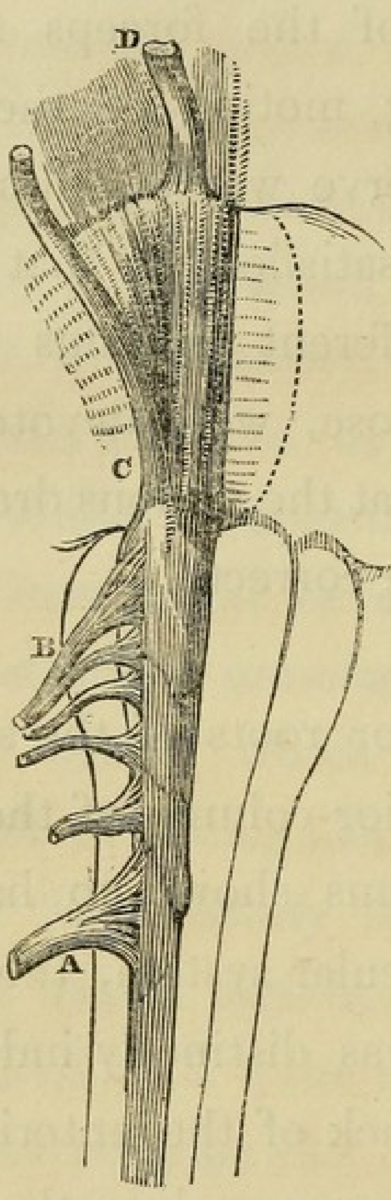
A the spinal marrow seen in front; B a spinal nerve; C the anterior root of the spinal nerve; D the ganglion on the posterior root.

The funiculi of the anterior roots of these nerves gather their minute origins with more irregularity than the posterior; and from a wider surface.

The thirty nerves thus formed of two distinct fasciculi, are suited to perform all the offices of the trunk and limbs. Is it, then, by that combination of properties which they acquire through their double roots, that they are capable of performing their offices? And is this the cause of their simplicity of arrangement in their course through the body, as contrasted with the nerves of the head? Again, what cerebral nerves, in their distribution to the head and face, correspond in office with the spinal nerves? On the solution of these questions will depend our knowledge of the whole nervous system.

It was necessary to know in the first place, whether the phenomena exhibited on injuring the separate roots of the spinal nerves corresponded with what was suggested by their anatomy. After delaying long on account of the unpleasant nature of the operation, I opened the spinal canal of a rabbit, and cut the posterior roots of the nerves of the lower extremity; the creature crawled, but I was deterred from repeating the experiment by the protracted cruelty of the dissection. I reflected, that an experiment would be satisfactory, if done on an animal recently knocked down and insensible; that whilst I experimented on a living animal, there might be a trembling or action exerted in the muscles by touching a sensitive nerve, which motion it would be difficult to distinguish from that produced more immediately through the influence of the motor nerves. I therefore struck a rabbit behind the ear, so as to deprive it of sensibility by the concussion, and then exposed the spinal marrow. On irritating the posterior roots of the nerve, I could perceive no motion consequent, on any part of the muscular frame; but on irritating the anterior roots of the nerve, at each touch of the forceps there was a corresponding motion of the muscles to which the nerve was distributed. These experiments satisfied me that the different roots and different columns from whence those roots arose, were devoted to distinct offices, and that the notions drawn from the anatomy were correct.

The anterior roots of the spinal nerves, and the anterior column of the spinal marrow, being thus shown to have a power over the muscular system, the next step of the enquiry was distinctly indicated. If I pursue the track of the anterior column of the spinal marrow up into the brain, shall I find the nerves which arise from it to be muscular nerves? An anatomist will at once answer, that only muscular nerves arise in this line.



We see here the anterior root of the spinal nerve, arising from the column at A. We trace the column up into the corpus pyramidale, and find there the origin of the ninth nerve B. We see that this nerve has only one series of roots, corresponding with the anterior roots of the spinal nerves, and that these roots come from the *tractus motorius*, and we cannot forget that this nerve is entirely devoted to the muscles of the tongue; that it is the motor of the tongue.

Following up the corpus pyramidale, we find issuing from it the sixth nerve, a muscular nerve of the eye. Still following up the *tractus motorius* through the *pons varolii*, we come to the roots of the third nerve, the motor nerve of the eye. Thus all the nerves arising in one line from the Crus Cerebri to the Cauda Equina are muscular nerves.

On finding this confirmation of the opinion, that the anterior column of the spinal marrow and the anterior roots of the spinal nerves were for motion, the conclusion presented itself that the posterior column and posterior roots were for sensibility. But here a difficulty arose. An opinion has prevailed that ganglia were intended to cut off sensation; while every one of the nerves, which I supposed were the instruments of sensation, had ganglia on their roots. See p. 28. D.

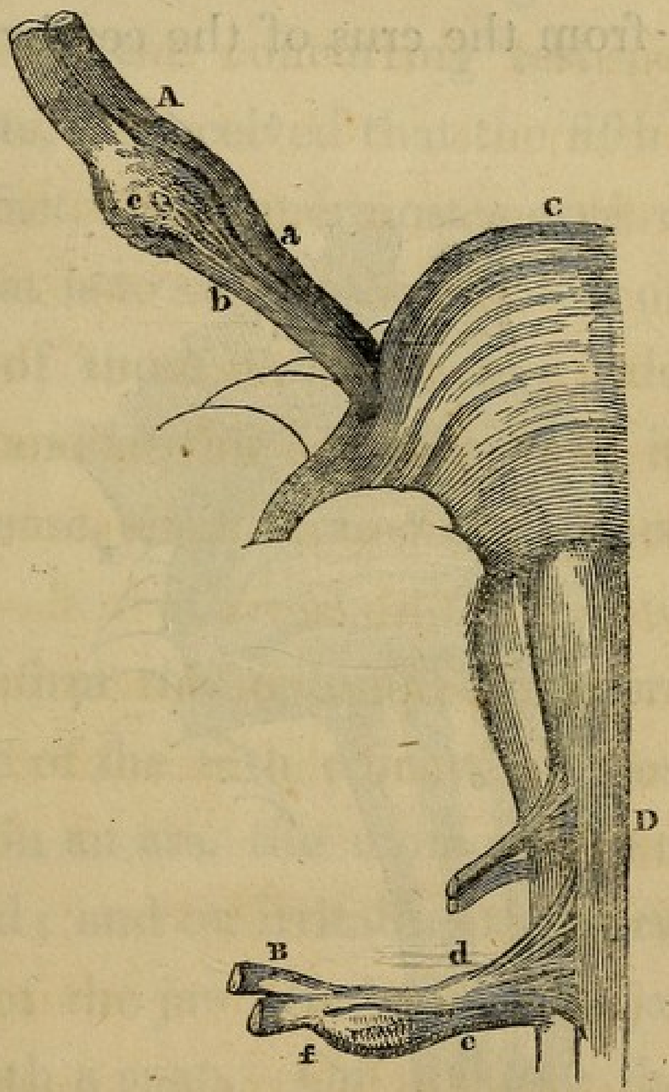
Some very decided experiment was necessary to overturn this dogma. I selected two nerves of the encephalon; the fifth, which had a ganglion, and the seventh, which had no ganglion. On cutting across the nerve of the fifth pair on the face of an ass, it was found that the sensibility of the parts to which it was distributed was entirely destroyed. On cutting across the nerve of the seventh pair on the side of the face of an ass, the sensibility was not in the slightest degree diminished.

By pursuing the enquiry, it was found that a ganglionic nerve is the sole organ of sensation in the head and face: and thus my opinion was confirmed, that the ganglionic roots of the spinal nerves, were the fasces or funiculi for sensation.

It now became obvious why the third, sixth, and ninth nerves of the encephalon were single nerves in their roots, as contrasted with the spinal nerves: for if the fifth nerve bestowed sensibility universally on the head and face and all the parts contained, there was no necessity, so to speak, for the third, sixth, and ninth, having the posterior or ganglionic root.

Pursuing the subject and still directed by the anatomy, the next matter of enquiry was to ascertain how far the fifth nerve of the encephalon corresponded with the spinal nerves. It was discovered that the fifth nerve bestowed sensibility on all the cavities and surfaces of the head and face. It was also observed, that where the sensibility of the integuments remained after the division of the fifth nerve, it was only to the extent of surface supplied by the nerves of the spine. Where certain fibrils of the spinal nerve extend upon the integuments of the side of the jaw, these are equivalent in office to those of the fifth nerve. In short, in regard to their property of bestowing sensibility, the fifth and the spinal nerves were identified.

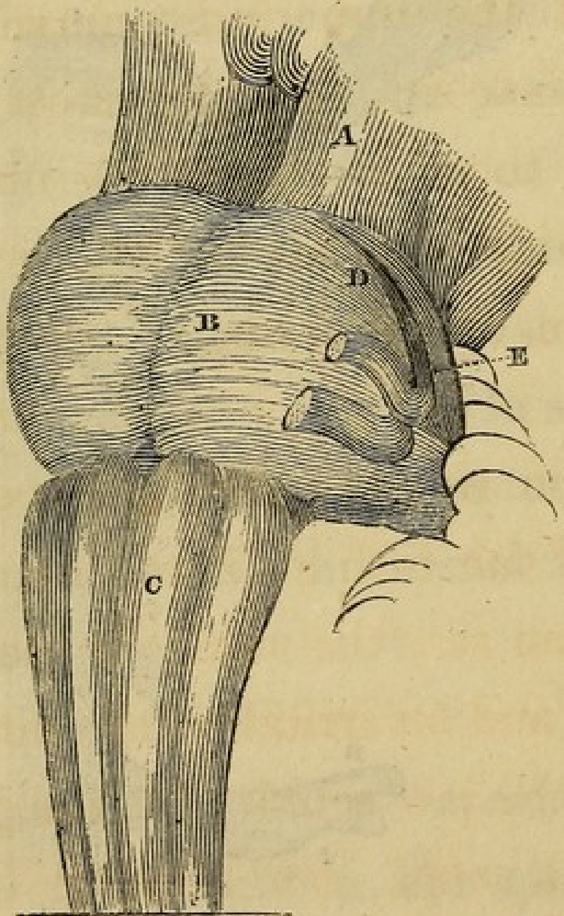
But was the fifth nerve in other essential circumstances similar to the spinal nerves? On recurring to the anatomy, and comparing the fifth nerve of the encephalon with a spinal nerve, the resemblance, both in man and brutes, was very remarkable. In this sketch we recognise corresponding parts. In both nerves we see the double roots; the anterior root passing the ganglion, and the posterior root falling into it



We have above an exact drawing of the 5th nerve, and one of the spinal nerves.

A the 5th nerve; B a spinal nerve; C the Pons Varolii; D the Corpus Pyramidale; a that origin of the 5th which has no ganglion; b the root of the 5th which has a ganglion; c the ganglion; d the anterior origin of the spinal nerve having no ganglion; e the posterior ganglionic root of the same nerve; f the ganglion.

or forming it. On following back the anterior root, we may perceive that it comes out betwixt the *funes* of the pons Varolii, and, in fact, from the crus of the cerebrum.



A Crus Cerebri; B Pons Varolii; C Medulla Oblongata; D two ropes or funes of the pons, which part to give origin to the anterior root of the 5th nerve; E a fasciculus from the Crus Cerebri, giving origin to the anterior root of the 5th nerve.

Observing that there was a portion of the fifth nerve, which did not enter the ganglion of that nerve, and being assured of this fact by the concurring testimony of anatomists, I conceived that the fifth nerve was in fact the uppermost nerve of the spine; that is to say, the uppermost or most anterior of those nerves which order the motion, and bestow sensibility, in its extended sense, on the frame of the body.

To confirm this opinion by experiment, the nerve of the fifth pair was exposed at its root, in an ass, the moment the animal was killed; and on irritating the nerve, the muscles of the jaw acted, and the jaw was closed with a snap. On dividing the root of the nerve in a living animal, the jaw fell relaxed. Thus its functions were no longer matter of doubt: it was at once a muscular nerve and a nerve of sensibility. And thus the opinion was confirmed, that the fifth nerve was to the head, what the spinal nerves were to the other parts of the body.

One circumstance I may notice in passing; the origin of the fifth nerve being above or anterior to the termination of the column of the spinal marrow for respiration, it can receive no roots from it. How then are the features to be moved in sympathy with the lungs, and with the respiratory actions of the breast, neck, and throat? We shall find presently that this is effected through the portio dura of the seventh.

I have now only to add, that these opinions and experiments have been followed up to the satisfaction of all Europe. It has been acknowledged that the anterior roots of the spinal nerves bestow the power of muscular motion; and the posterior roots sensibility. When the anterior roots of the nerves of the leg are cut in experiment, the animal loses all power over the leg, although the limb still continues sensible. But if, on the other hand, the posterior roots are cut, the power of motion continues, although the sensibility is destroyed. When the posterior column of the spinal marrow is irritated the animal evinces sensibility to pain; but no apparent effect is produced when the anterior column is touched.

I shall now proceed, by reference to the plate, to explain the SYMMETRICAL SYSTEM OF NERVES. We see thirty-one nerves similar in origin and constitution, ranging with perfect order, and going forth to the head, body, and limbs in regular succession; and in their essential attributes, common to every class of animals, from the creeping thing* up to man.

* This will be condemned as a term not systematic, but it is strictly correct. It is the necessity of a correspondence in the motions of the body and feet which, if we may so express it, calls for symmetry in the distribution of the nervous system. When a creature has no feet, or substitute for them, there is no symmetrical system of nerves. If we were to consider the necessity of correspondence in the motions of the hands and feet, as well as in the four quarters of brutes, that each foot does not move by itself, but, on the contrary, that there is a combination of motion betwixt the limbs in walking, ambling, trotting, gallopping, &c., we should see that the muscular system must be united by a longitudinal cord and uniformity of branches going out laterally.

EXPLANATION OF PLANS.

When we contemplate the dissection which we have made of the nerves of the face, neck, and chest, and are lost in the confusion of the VIIth, VIIIth, and IXth of the branches of the Cervical Nerves, and of the Sympathetic—of the Diaphragmatic, Spinal Accessory, and Inferior External Respiratory Nerves—we shall be prepared to see the advantages of the plans which are annexed. The reader will soon discover that the system, of which the plans may give him some idea, is not only a remarkable improvement in the knowledge of the structure and functions of animal bodies, but is of the greatest use in practical anatomy in facilitating the comprehension of the nerves.

The arrangement is this: — There is an obvious division of the medulla spinalis corresponding to the cerebrum and cerebellum: every regular nerve has two roots, one from the anterior of these columns, the other from the posterior: such are the Vth
7 pair; the Suboccipital; the ~~six~~ Cervical; the twelve Dorsal; the five Lumbar; and the six Sacral; viz., thirty-one pairs of perfect, regular, or double nerves in the human body. These are laid down in the first plan. They are common to all animals, from the worm up to man; and are for the purposes of common sensation and motion, or acts of volition; they run out laterally to the regular divisions of the body, and never take a course longitudinal to the body.

For the sake of arrangement, the remaining nerves are called IRREGULAR NERVES. These are distinguished by a single fasciculus, or single root; that is a root from one column. These are *simple* in their origin; *irregular* in their distribution; and deficient in that symmetry which characterizes the first class. They are superadded to the original class, and correspond to the number and complication of the superadded organs. Of these there are—the IIId, IVth, and VIth to the eye; the VIIth to the face; the IXth to the tongue; the *Glosso Pharyngeal* to the pharynx; the *Nervus Vagus* to the larynx, heart, lungs, and stomach; the *Phrenic* to the diaphragm; the *Spinal Accessory* to the muscles of the shoulder; the *External Respiratory* to the outside of the chest.

If we enquire into the seeming confusion in the second class, or *irregular nerves*, we shall perceive that it is owing to the complication of the superadded apparatus of respiration, and the variety of offices which this apparatus has to perform in the higher animals. To explain this the second plan is given. It presents in one view the nerves destined to move the muscles in all the varieties of respiration, speech, and expression.

We may now see how confounding is the numbering of the nerves, according to the system of Willis ; and how impossible it is to make a natural arrangement while the nerves are so numbered.

EXPLANATION OF PLATE I.

A A Cerebrum.

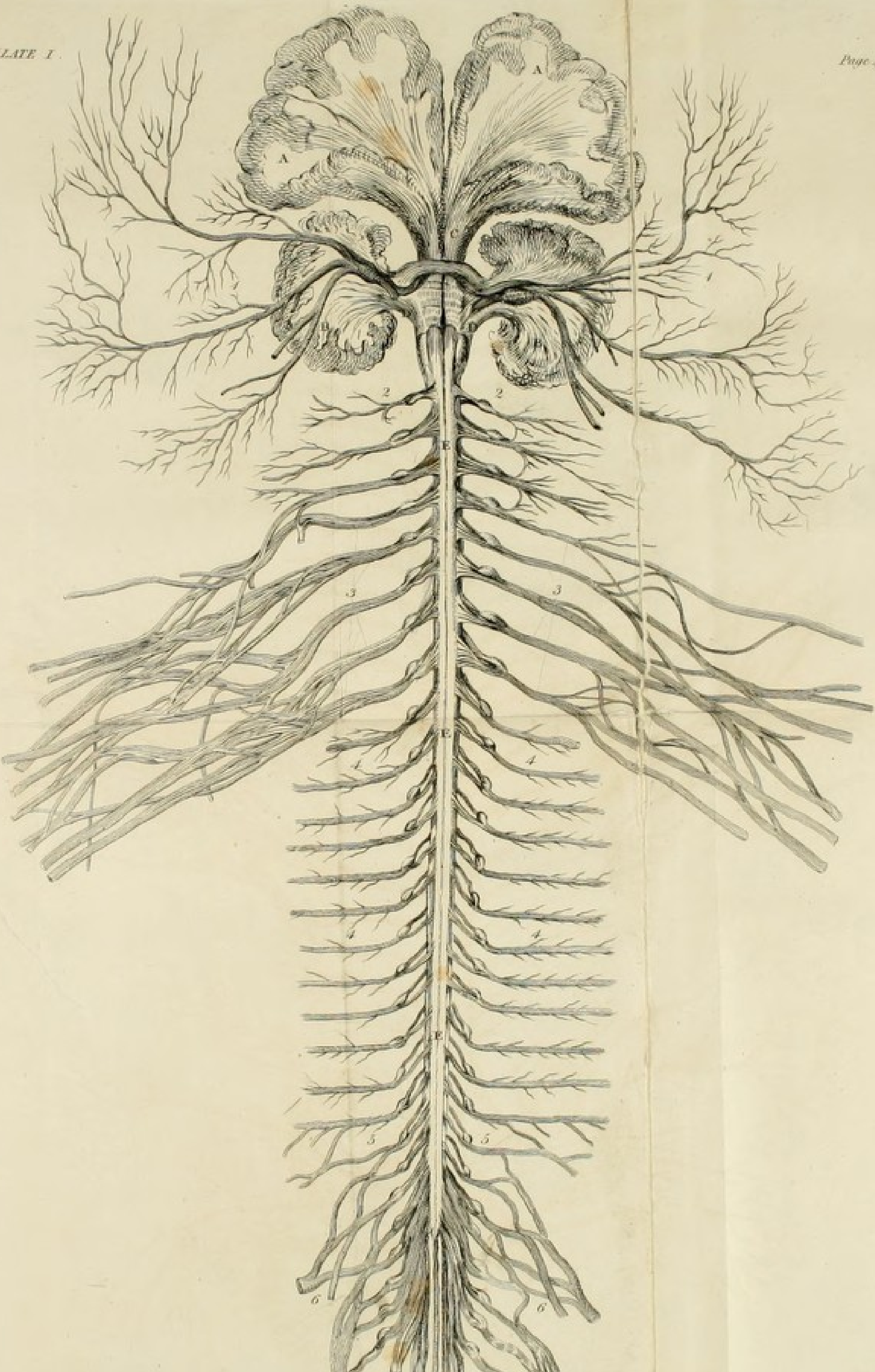
B B Cerebellum.

C C Crura Cerebri.

D D Crura Cerebelli.

E E E Spinal marrow.

1 1 Branches of the Vth pair, or Trigeminus, which are seen to arise from the union of the Crura Cerebri and


A
A
C
2
2
E
3
3
E
4
4
4
4
E
5
5
6
6

crura cerebelli: one root coming from the crus cerebri, and another from the crus cerebelli; and on the last a ganglion is seen, like the ganglion of the spinal nerves. The branches of the Vth nerve are universally distributed to the head and face.

2 2 Branches of the *Suboccipital* Nerves, which have double origins and ganglions.

3 3 The branches of the four inferior Cervical Nerves and of the first Dorsal, forming the Axillary Plexus: the origins of these nerves are similar to those of the Vth and the Suboccipital.

4 4 4 4 Branches of the Dorsal Nerves, which also arise in the same manner.

5 5 The Lumbar Nerves.

6 6 The Sacral Nerves.

OF THE SYSTEM OF NERVES CALLED RESPIRATORY.

The observation of the frame of man or of brute, and especially the review of it in a state of high activity, or under the influence of passion, will convince us that the motions dependent on respiration extend almost over the whole body, while they more directly affect the trunk, neck, and face. We may perceive, also, that during the involuntary action of respiration the same muscles are in operation as in the voluntary actions. This is evident not only in breathing, but also in coughing, sneezing, crying, laughing, speaking, swallowing, and vomiting; for all these are states or conditions of the respiratory nerves and muscles. In every effort but that of simple voluntary motion, the respiratory organs become the agents; and even in violent voluntary efforts, or the long continuance of exercise, the instinctive motions chime in with the voluntary motions, and the activity of the frame becomes general.

Under the class of respiratory motions we have to distinguish two kinds: first, the involuntary, or instinctive; secondly, those which accompany an act of volition. We are unconscious of that state of alternation of activity and rest which characterises the instinctive act of breathing in sleep; and this condition of activity of the respiratory organs we know, by experiment, is independent of the brain. But, on the other hand, we see that the act of respiration is sometimes an act of volition, intended to accomplish some other operation, as that of smelling or speaking. I apprehend that it is this compound operation of the organs of breathing which introduces a certain degree of complexity into the system of respiratory nerves. A concurrence of the nerves of distinct systems will be found necessary to actions which at first sight appear to be very simple.

To make this evident, before proceeding further, I shall give an example of the necessity of this combination of different powers. Let us observe, in the act of eating and swallowing, the necessary combination of the three powers of sensation, voluntary muscular activity, and the act of the respiratory muscles.

If we cut the divison of the fifth nerve which goes to the lips of an ass, we deprive the lips of sensibility: so when the animal presses the lips to the ground, and against the oats lying there, it does not feel them; and consequently there is no effort made to gather them. If, on the other hand, we cut the seventh nerve where it goes to the lips, the animal feels the oats, but it can make no effort to gather them, the power of muscular motion being cut off by the division of the nerve. Thus we perceive that in feeding, just as in gathering any thing with the hand, the feeling directs the effort; and two properties of the nervous system are necessary to a very simple action.

In drinking, the fluid is sucked in by the breath, and when the mouth is full we swallow. The water is felt; the lips are moulded into the right form by volition, and the muscles of inspiration combine to draw in the fluid. In the act of swallowing, the liquid would descend into the windpipe were there not a combination of the muscles of respiration with the apparatus of deglutition to prevent it; nor could the fluid or the solid morsel pass the diaphragm without a similar coincidence of activity and relaxation betwixt parts animated by different system of nerves.

In speaking, it is still more obvious that the act of respiration must become voluntary, in order to push out the breath in combination with the contractions of the larynx, and tongue and lips, for producing sound, and more especially articulate language.

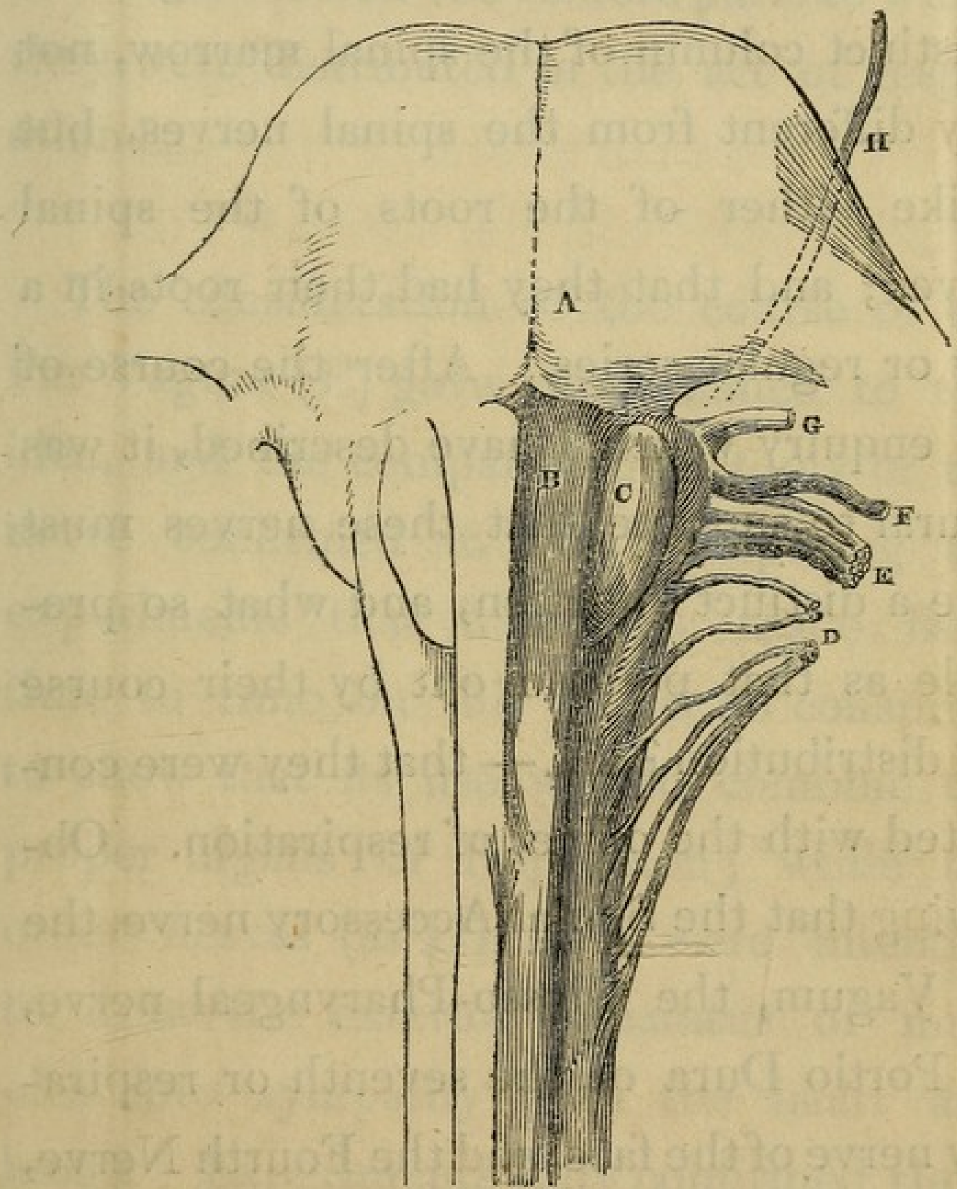
The respiratory system must be exercised under an instinctive and involuntary impulse, as in breathing during sleep and insensibility. But it must, at certain times, be associated into voluntary actions. By foreseeing this difficulty we shall avoid the danger of pushing the investigation of the anatomy too far; or of throwing a doubt over important discoveries by attempting too much.

After the investigation of the regular system of nerves of sensation and voluntary motion, the question that had so long occupied me, viz.—what is the explanation of the excessive intricacy of the nerves of the face, jaws, throat, and breast? became of easy solution. These nerves are agents of distinct powers; and they combine the muscles in subserviency to different functions.

As far as regards motion and sensation, the original and symmetrical nerves appeared sufficient to the concatenation of the muscles. By them creatures feel pain, and move and withdraw themselves from injury. But these nerves are not capable of (that is to say, were not designed for) the vital act of respiration, far less for smelling, speaking, singing, laughing, in which several acts the respiratory system is brought into activity.

As animals rise in the scale of beings, new organs are bestowed upon them. And as new organs and new functions are superadded to the original constitution of the frame, new nerves are given also, and new sensibilities, and new powers of activity.

In the act of respiration we see a succession of regular motions extending to a great part of the animal machinery; we perceive, at one glance, that this is a new species of activity, and that this new energy must be derived from a source different from locomotive powers. Looking to the simultaneous motions of the abdomen, thorax, neck, throat, lips, and nostrils, in breathing, it is obvious, in the first place, that they must be animated by nerves partaking of similar powers; and that these nerves must have a centre somewhere, so that they may be simultaneously and equally excited, and give a uniform impulse to the muscles of respiration.



A the Pons Varolii; B Corpus Pyramidale; C Corpus Olivare; D The Spinal Accessory nerve; E Par Vagum; F Glosso-Pharyngeal nerve; G Portio Dura of the seventh; H Fourth nerve.

All these are respiratory nerves, arising in a line from the same column.

The reader will now understand the course of my reflections, when I observed that there were certain nerves arising from a distinct column of the spinal marrow, not only different from the spinal nerves, but unlike either of the roots of the spinal nerves; and that they had their roots in a row or regular series. After the course of the enquiry which I have described, it was natural to suppose that these nerves must have a distinct function, and what so probable as that pointed out by their course and distribution? viz.—that they were connected with the offices of respiration. Observing that the Spinal Accessory nerve, the Par Vagum, the Glosso-Pharyngeal nerve, the Portio Dura of the seventh or respiratory nerve of the face, and the Fourth Nerve, arose in a distinct tract and in sequences, I conceived that they offered themselves as fair subjects of experiment; and that by an experiment the question would be determined, viz. — whether or not these five nerves connected the remote parts to which they were distributed in the act of respiration?

The consideration of the course of the Par Vagum (E) gave countenance to this idea, and the comparative anatomy of the nerve confirmed it. On comparing the experiments that had been made from time to time on this nerve, all conspired to show that its use was to combine the proper organs of respiration; while the other nerves (as DFGH) were intended to draw the exterior apparatus of muscles into sympathy with the heart and lungs. Experiments fully confirmed these opinions.

In this course of enquiry it was natural to ask why the Spinal Accessory of authors

(D) arose from the spinal marrow in the neck? why it ascended into the head, to join itself with the par vagum, instead of following the direct and short route to its destination on the muscles of the neck and shoulder, like the spinal nerves? I divided its branches in the living animal, and by that means cut off certain muscles from partaking in the act of breathing, while they retained their office under the other nerves; that is, they remained under the direction of the will when they had ceased to be influenced by the lungs.

Directed in the next place to the Portio Dura (G), I wished to answer the question, Why does the nerve which supplies the muscle of the face take an origin and a course different from the Fifth Nerve destined to the same parts? By experiment I proved that this was the respiratory nerve of the face: and by inference I concluded, that it had the origin we see, and took its course with the respiratory nerves; because it was necessary to the association of the muscles of the nostrils, cheek, and lips, with the other muscles used in breathing, speaking, &c. For this reason it was associated with the root of the Eighth Pair instead of the Fifth.

The course of enquiry into the functions of the branches of the Portio Dura which go to the eyelids, led me to make observations on the motions of the eyeball; and finally directed me to the Fourth Nerve (H) to account for the sympathetic motions of the eyeball in combination with the other parts moved in the excited state of respiration.

I may here observe, that on thrusting a pin or the probe into the substance of the medulla oblongata near the root of the portio dura (G), and then turning to the other side, we shall find that we have thrust betwixt the roots of the fourth nerve.*

This intricate subject is discussed in the last of the series of papers given to the Royal Society, and republished in this volume.

Nothing can better prove the importance of the principles laid down in the beginning of this exposition than the explanation which it offers of the seeming intricacy of the nerves of the orbit and of the whole head and face; and the variety of curious facts which it brings to light. These, as I have said, are detailed in the last of these papers.

It appears, then, that there are four nerves coming out of a track or column of

* I have indicated the course of the fourth nerve by a dotted line.

the spinal marrow, from which neither the nerves of sensation, nor of common voluntary motion take their departure. Experiment further proves, that these nerves excite motions dependent on the act of respiration.

There can be no hesitation or doubt that as far as the neck, throat, face, and eyes depend on, or are related to the actions of respiration, it is through these nerves that they are so associated.

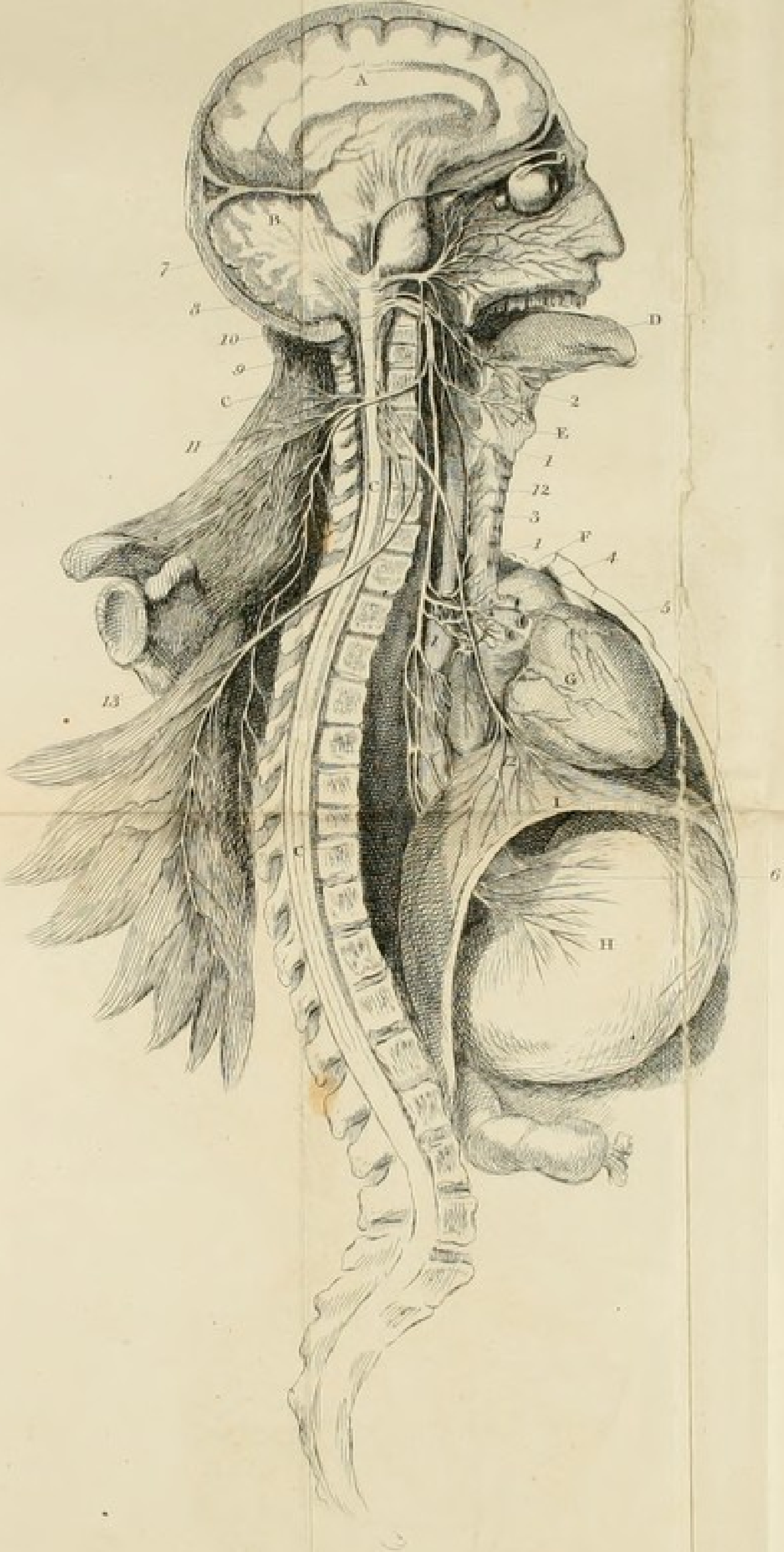
I have been always desirous of stating, that the absolute proofs stop here, and that the rest is hypothesis. I imagine that the same column or track which gives origin to the fourth, seventh, glosso-pharyngeal, par vagum, and spinal accessory nerves is continued downward along the lateral part of the spinal marrow, and that it affords roots to the spinal nerves, constituting them respiratory nerves as well as nerves of motion and sensation; and that it especially supplies the roots of the diaphragmatic nerve, and the external respiratory nerve.

The spinal nerves are adequate to the gentle and uniform motions of respiration, but not to the associated actions of respiration. Thus when a creature cries, or a man speaks or sings, the muscular effort is not in the muscles of the thorax only, and directed by the intercostal nerves; but the shoulders are raised and the thorax expanded by the influence of the spinal accessory nerve, and the external respiratory nerves. The larynx is excited by the branches of the par vagum called laryngeal. The cheeks, lips, and nostrils, are directed by the portio dura and the fourth nerves.

It is remarkable that in the investigation of this subject every nerve and twig of

PLATE II

Plan of the Nerves of Respiration.



nerve is accounted for, and its office explained, with the exception of certain divisions of the sixth nerve of the brain.

EXPLANATION OF PLATE II.

A Cerebrum.

B Cerebellum.

C C Spinal Marrow.

D Tongue.

E Larynx.

F Bronchia.

G Heart.

H Stomach.

I Diaphragm.

1 1 1 Par Vagum, arising by a single set of roots and passing to the larynx, the lungs, heart, and stomach.

2 2 Superior laryngeal branches of the par vagum.

3 Recurrent or inferior laryngeal of the par vagum.

4 Pulmonic plexus of the par vagum.

5 Cardiac plexus of the par vagum.

6 Gastric plexus or corda ventriculi of the par vagum.

7 Fourth nerve a branch of this system to the eye.

8 Respiratory nerve or portio dura to the muscles of the face, arising by a series of single roots.

9 Branches of the glosso-pharyngeal.

10 Origins of the superior external respiratory or spinal accessory nerve.

11 Branches of the last nerve to the muscles of the shoulder.

12 12 12 Internal respiratory, or the phrenic to the diaphragm. The origins of this nerve may be seen to pass much higher up than they are generally described.

13 Inferior external respiratory to the serratus magnus.

It was said that we understand the use of all the intricate nerves of the body, with the exception of the sixth. The sixth nerve stands connected with another system of nerves altogether; I mean the system hitherto called the sympathetic, or sometimes the ganglionic system of nerves; and of this system we know so little, that it cannot be matter of surprise if we reason ignorantly of the connection of the sixth with it.

Drawn by C. Bell.

Engraved by J. Stewart.

On reviewing the whole nerves of the human body, the sensitive, motor, and respiratory systems combined, surely these views come strongly recommended. They present a series of facts unexampled for their number and importance. Such, for instance, as the distinct functions of the nerves of the face; the fact that all sensibility in the head and face depends solely on the fifth nerve; the singular circumstance, that the common sensibility of the whole frame results from a series of ganglionic nerves extending from the head to the sole of the foot; that the act of respiration in the face, nostrils, throat, &c. results from a series of nerves differing from the common nerves: and last of all, it will not be said that I have left the question unresolved with which I set out, viz., the cause of the intricacy of the nerves of the face, neck, and chest. I have shown that the same part, as for example the tongue, has different nerves suited to its different functions; and that the intricacy arises from the interweaving of the branches of different systems. But all this has an easy explanation when we know the properties of the columns from which they proceed.

If there were no facts to give proof of the truth of the view which I have presented, it would surely be enough to recommend it, that a subject which has been hitherto difficult, and intricate, and forbidding, has, by means of it, become interesting, simple, and satisfactory.

I shall now lay before my reader the papers which I presented to the Royal Society on this subject, and in the order they are printed in the Philosophical Transactions.

ON

THE NERVES;

GIVING

AN ACCOUNT OF SOME EXPERIMENTS ON THEIR STRUCTURE AND FUNCTIONS,

WHICH LEAD TO

A NEW ARRANGEMENT OF THE SYSTEM.

From the Philosophical Transactions, 1821.

ON THE NERVES, &c.

[*Read before the Royal Society, July* 12, 1821.]

During the general advancement of science which has lately taken place in this country, observations have been gradually accumulating in the schools of the metropolis, which prove that the department of anatomy has not been stationary. The nervous system, hitherto the most unsatisfactory part of a physiologist's studies, has assumed a new character. The intricacies of that system have been unravelled, and the peculiar structure and functions of the individual nerves ascertained; so that the absolute confusion in which this subject was involved has disappeared, and the natural and simple order has been discovered.

In proceeding to give some account of these new observations, the author of this paper had conceived, that it would be more suitable to the scientific body he had to address, to lay the subject before them in the precise manner in which it first presented itself to his enquiries, and to detail his observations and experiments in the succession in which they were made; but he has been persuaded by some of the members of this society to change that form, and to present the subject in the manner to which he has been accustomed, in teaching these doctrines; and they were pleased to say, that in this way, a new subject would be more readily comprehended. *

* I believed that general attention to these subjects could not be raised by the account of a system founded

Intricacy of the Nervous System.

Anatomists have of late, not only in this country, but also in Germany and Italy, made great improvement in the minute dissection and display of the nerves; but whilst the doctrines hitherto received prevail, the discovery of new branches of nerves, and new ganglia, only involve the subject in deeper obscurity. Whilst the nerves are supposed to proceed from one great centre, to have the same structure and functions, and to be all sensible, and all of them to convey what has been vaguely called nervous power, these discoveries of new nerves and ganglia are worse than useless; they increase the intricacy, and repel enquiry. The endless confusion of the

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on anatomy, and on the minute distinctions in the origins of the nerves. I thought that it required the announcement of some distinct and remarkable facts.

subject induces the physician, instead of taking the nervous system as the secure ground of his practice, to dismiss it from his course of study, as a subject presenting too great irregularity for legitimate investigation or reliance.

When the physiologist sees two distinct nerves, spreading their branches to every part of the face, (as in the Plate of these nerves,) three nerves from different sources given to the tongue, four to the throat, and nerves in most perplexing intricacy to the neck; when he finds one nerve with numerous ganglia or knots upon it, and another without them; when, in short, after a minute dissection of the nervous system, he finds a mesh, or network, spreading everywhere, it is not surprising that the seeming intricacy and confusion should make him, in despair, resign enquiry

But the author of this paper, being forced in the course of his duty, to go minutely over the demonstration of the nerves, year after year, without allowing himself to resign the subject merely on account of its intricacy, and finding the facts which he had to explain in his demonstrations of the anatomy, quite inconsistent with the received opinions, he gradually, after much study, was enabled to decypher and to read that language, of which the character had hitherto been imperfectly known; and now even the youngest students are brought to comprehend so much of the subject, that the idea of chance or accident, or real confusion among these numerous branches, is entirely dismissed; and what remains unexplained has, by the success of our past enquiries, become a subject of peculiar interest, from the conviction, that attention to the minute anatomy, under the guidance of cautious and fair induction, will sooner or later lead to a comprehension of the whole system.

Statement of the object of the paper.

The author means to limit his present enquiry to *the nerves of respiration.* But according to his conception of this matter, these nerves form a system of great extent, comprehending *all the nerves which serve to combine the muscles employed in the act of breathing and speaking.*

The first point of enquiry naturally is, how many of the muscles are combined in the act of respiration? and the second question, by what means are these muscles, which are seated apart from each other, and many of them capable of performing distinct offices, combined together in respiration? It may sound oddly to speak of the respiratory nerve of the face, of the neck, and of the shoulder; and it may be necessary to give an illustration of the sense in which the term is intended to be employed. When a post-horse has run its stage, and the circulation is hurried and the respiration excited, what is his condition? Does he breathe with his ribs only; with the muscles which raise and depress the chest? No. The flanks are in violent action; the neck as well as the chest is in powerful excitement; the nostrils as well as the throat keep time with the motion of the chest. So if a man be excited by exercise or passion, or by whatever accelerates the pulse, the respiratory action is extended and increased; and, instead of the gentle and scarcely perceptible motion of the chest, as in common breathing, the shoulders are raised at each inspiration, the muscles of the throat and neck are violently drawn, and the lips and nostrils move in time with the general action; and if he does not breathe through the mouth, the nostrils expand, and fall in time with the rising and falling of the chest; and that apparatus of cartilages and muscles of the nose (which are as curious as the mechanism of the chest, and which are for expanding these air tubes), are as regularly in action as the levator and depressor muscles of the ribs.

It is quite obvious, that some hundred muscles thus employed in the act of breathing, or in the common actions of coughing, sneezing, speaking, and singing, cannot be associated without cords of connection or affinity, which combine them in the performance of these actions: the nerves which serve this purpose, I call respiratory nerves.

The nerves of the animal frame are complex, in proportion to the variety of functions which the parts have to maintain.

When we minutely and carefully examine the nerves of the human body, and compare them with those of other animals, a very singular coincidence is observed between the number of organs, the compound nature of their functions, and the number of nerves which are transmitted to them. No organ which possesses only one property or endowment, has more than one nerve, however exquisite the sense or action may be; but if two nerves, coming from different sources, are directed to one part, this is the sign of a double function performed by it. If a part, or organ, have many distinct nerves, we may be certain that, instead of having a mere accumulation of nervous power, it possesses distinct powers, or enters into different combinations, in proportion to the number of its nerves. The knowledge of this circumstance, gives new interest to the investigation of this part of anatomy.

Thus, in reviewing the comparative anatomy of the nerves of the mouth, we shall find, that in creatures which do not breathe, the mouth having only one function to perform, one nerve is sufficient. In certain animals where the face and nostrils have no complexity of relations, these parts have only a single nerve. If the throat has no complexity of organization, it has no variety of nerves. But on the other hand, when the anatomist employs weeks to dissect and disentangle the nerves of the tongue, throat, and palate, in the human subject, he finds at length, that he has exhibited the branches of five different trunks of nerves; and there is no clue to the labyrinth, until he considers the multiplied offices of the mouth in man; that it is a pneumatic as much as a manducatory organ; that it is the organ of the voice and of speech, as of taste and exquisite feeling. It would, indeed, be matter of surprise, if the same nerve served for the action of gnawing and feeding in the lower animals of simple structure, and also for the governance of those complicated operations, which serve to interpret the wants and sentiments of man.

Such are the views which naturally arise, from an acquaintance with the nerves of the human body; but a comparison of them, with those of the lower classes of animals, enables us to establish a more lucid order; and that not in an arbitrary manner, but perfectly according to nature.

The nerves may be divided into two parts, or systems; the one simple and uniform, the other irregular and complex, in proportion to the complexity of organization.

When the nerves of the face, mouth, throat, and neck of the human subject are minutely displayed, it seems impracticable to reduce the numerous nerves which cross and entwine with each other to two distinct classes; yet nothing is more certain than that this may be done, and by an easy and natural method.

The principle which is to guide us, is obtained by ascertaining what parts of the organization of an animal are necessary to life and motion; what organs are superadded as the animal advances in the scale of existence, as necessary to higher and more complex enjoyments and actions.

Where an animal is endowed with mere sensation and locomotion, where there is no central organ of circulation, and no organ of respiration but what is generally diffused over the frame, the nerves are extremely simple; they consist of two cords running in the length of the body, with branches going off laterally to the several divisions of the frame. And here no intricacy is to be seen, no double supply of nerves is to be observed, but each portion of the frame has an equal supply; and the central line of connection is sufficient to combine the actions of the muscles, and to give them the concatenation necessary to locomotion.

There is the same uniform and symmetrical system of nerves in the human body as in the leech or worm; although obscured by a variety of superadded nerves. These additional nerves belong to organs, which, tracing the orders of animals upward, are observed gradually to accumulate until we arrive at the complication of the human frame. These nerves, additional and superadded to the original system, do not destroy, but only obscure that system; and accordingly, when we separate certain nerves, the original system of simple constitution is presented even in the human body.

The nerves of the spine, the tenth or sub-occipital nerve, and the fifth or trigeminus of the system of Willis, constitute this original and symmetrical system.* All

* The following note is from a paper by Mr. Shaw. To those who have interested themselves in these dis-

these nerves agree in these essential circumstances ; they have all double origins ;

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coveries, during their progress, I need not say how much I am obliged to him, and with what ability he has advocated my opinions. Often I have felt satisfied with ascertaining the facts, when he has excited me to further enquiry, and to shape them for the public.

" *Comparison betwixt the Fifth and the Spinal Nerves.*

" 1. That the head and face, having many parts in every respect similar to the neck, trunk, and limbs, must have corresponding nerves.

" 2. That the manner in which the spinal nerves and the fifth arise by double origins, is very similar.

" 3. That the ganglion on the root of the fifth nerve, has a strict resemblance to the ganglia at the origin of the spinal nerves.

" 4. That the manner in which the branches of the fifth are distributed, and those of the spinal nerves, is the same.

" And, lastly, with reference to the anatomy, we find that the same kind of connexion exists between the fifth and the sympathetic, as between the latter and the spinal nerves. In their morbid affections, the similarity also holds good: thus, in the common cases of hemiplegia, the spinal nerves and the branches of the fifth are similarly affected. In this disease, the voluntary power they have all ganglia on one of their roots; they go out laterally to certain divisions of

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over the limbs, and the sensibility of the side affected, are generally destroyed; while in some cases the voluntary power is lost, and the sensibility continues unimpaired, or *vice versa.* This variety also occurs on the face; for the jaw will drop, and there will be all the marks of paralysis, while the sensibility of the skin and the sense of taste continue entire.

" In experiments on the nerves of the spine and on the fifth, we meet with the same results. If, as in the operation, which is now frequently performed on the nerves of the horse's foot, we cut a spinal nerve after the branches are given off to the muscles moving the part, we shall destroy only the sensibility of that part; but, if we cut the nerve nearer to the brain, we shall not only destroy the sensibility, but also the power of motion. The same happens in experiments on the fifth; for, if we cut a branch which is distributed principally to the skin of the lips, we shall destroy the sensibility of the part, but impair the power of mastication only in a slight degree; but if we divide the nerve further back, then we shall not only destroy the sensibility of the skin, as in the first experiment, but also cut off the power by which the jaws are moved. I cut a branch of the fifth upon the face; the sensibility of the corresponding side of the lip was destroyed, but little paralysis ensued. I cut the nerve nearer the brain, and at a point previous the body; they do not interfere to unite the divisions of the frame; they are all muscular nerves, ordering the voluntary motions of the frame; they are all exquisitely sensible; and the source of the common sensibility of the surfaces of the body: when accurately represented on paper, they are seen to pervade every part; no part is without them; and yet they are symmetrical and simple as the nerves of the lower animals. See Plate I.

If the nerves be exposed in a living

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to its having given off the branches to the muscles; then the jaw fell, and the muscles of that side were powerless. I varied the experiment, by irritating the nerve where it lies in the spheno-palatine fissure, immediately after an animal was killed: the jaws then came together with much force, indeed, so as to nip my assistant's finger severely. This last experiment may be compared with the very common one of galvanizing the nerves which pass from the spinal marrow, to supply the muscles of the extremities."

animal, those of this class exhibit the highest degree of sensibility; while, on the contrary, nerves not of this original class or system, are comparatively so little sensible, as to be immediately distinguished; in so much that the quiescence of the animal suggests a doubt, whether they be sensible in any degree whatever. If the *fifth nerve, and the portio dura of the seventh*, be both exposed on the face of a living animal, there will not remain the slightest doubt in the mind of the experimenter, which of these nerves bestows sensibility. If the nerve of this original class be divided, the skin and common substance are deprived of sensibility; but if a nerve not of this class be divided, it in no measure deprives the parts of their sensibility to external impression.

More particularly of the respiratory nerves.

The nerves which connect the internal organs of respiration with the sensibilities of remote parts, and with the respiratory muscles, are distinguished from those of which we have been speaking by many circumstances. They do not arise by double roots; they have no ganglia on their origins; they come off from the *medulla oblongata* and the upper part of the spinal marrow; and from this origin, they diverge to those several remote parts of the frame, which are combined in the motion of respiration. These are the nerves which give the appearance of confusion to the dissection, because they cross the others, and go to parts already plentifully supplied from the other system.

The following are the nerves to be enumerated as *respiratory nerves*, according to their functions.

1. *Par vagum*, E,* the eighth of Willis, the *pneumogastric nerve* of the modern French physiologists. This nerve goes off from the common origin of the respiratory nerves, the lateral part of the *medulla oblongata*; it takes its course to the larynx, the lungs, the heart, and stomach. It associates these organs together, which are at the same time supplied with nerves from other sources. Comparative anatomy would lead us to infer that this nerve is not essential to the stomach, as it does not exist but where there are heart and lungs to associate with a muscular apparatus of respiration. That the stomach must be associated with the muscular apparatus of respiration, as well as the lungs, is obvious,

* These letters have reference to the wood-cut at p. 55.

from the consideration of what takes place in vomiting and hiccough, which are actions of the respiratory muscles excited by irritation of the stomach.

2. *Respiratory nerve of the face*, G, being that which is called *portio dura* of the seventh. This nerve, like the last, goes off from the lateral part of the *medulla oblongata*, and, escaping through the temporal bone, spreads wide to the face. All those motions of the nostril, lips, or face generally, which accord with the motions of the chest in respiration, depend solely on this nerve. By the division of this nerve, the face is deprived of its consent with the lungs, and all expression of emotion. This part of the enquiry will be found very interesting.

3. *Superior respiratory nerve of the trunk*, D, being that which is called *spinal*

accessory. This nerve has exceedingly puzzled anatomists, from the singular course which it pursues. It arises from the superior part of the spinal marrow, in a line with the roots of the other respiratory nerves. Instead of going directly out betwixt the vertebræ, as the regular spinal nerves do, it passes up into the skull, comes out through the skull with the par vagum, and, descending upon the neck, goes to the muscles of the shoulder. In this course it supplies muscles, which are already profusely supplied by the regular system of nerves.

This nerve controls the operations of the muscles of the neck and shoulder in their office as respiratory muscles, when, by lifting the shoulders, they take the load from the chest, and give freedom to the expansion of the thorax. When it is cut across in experiments, the muscles of the shoulder, which were in action as respiratory muscles, cease their co-operation, but remain capable of voluntary actions.

4. *Great internal respiratory nerve.* The *phrenic* or *diaphragmatic*, of authors. (See Plate II.) This is the only nerve of the system which has been known as a respiratory nerve. Its origin, course, and destination, are so familiar to every one, that I shall not say anything more of it here. But there is another nerve, which has a remarkable resemblance to it, and which, from circumstances already noticed, has been entirely overlooked. This is,

5. *The external respiratory nerve.* (See Plate II.) This has a similar origin with the preceding nerve. It comes out from the cervical vertebræ, and is connected with the phrenic nerve. It runs down the neck, crosses the cervical and axillary nerves,

passes through the axilla, and arrives on the outside of the ribs, where, it is scarcely necessary to observe, the muscles are already supplied by nerves coming out betwixt the ribs, from the system of regular nerves.

These four last-mentioned nerves govern the muscles of the face, neck, shoulders, and chest, in the actions of excited respiration, and are absolutely necessary to speech and expression. But there are other nerves of the same class which go to the tongue, throat, and windpipe, no less essential to complete the act of respiration. These are the glossopharyngeal nerve, F, the lingual or ninth of Willis, and the branches of the par vagum to the superior and inferior larynx. *

* It will be seen that in the further investigation of this subject, the 4th nerve, H, was discovered to belong

We proceed to examine these nerves in detail; and, first,

Of the nerves of the face, in which it is shown that the two sets of nerves, hitherto supposed to be similar, differ in structure, sensibility, and function. *

It is in the face, that we have the best opportunity of observing the subservience of the nerves to the uses of the parts, and of ascertaining the truth of the preceding doctrines. The human countenance performs many functions: in it we have combined the organs of mastication, of breathing, of natural voice and speech, and of expression. These motions are performed

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to this system. — See the paper on the Nerves of the Orbit.

* This subject is illustrated by Plate III. which represents the nerves of the face.

directly by the will; here also are seen signs of emotions, over which we have but a very limited or imperfect control; the face serves for the lowest animal enjoyment, and partakes of the highest and most refined emotions. Happily for our present object, the nerves, which in other parts of the frame are bound together for the convenience of distribution to remote parts, are here distinct, and run apart from each other until they meet at their extremities. They take different courses through the bones of the head, and come out upon the face, to be exposed in a manner which courts enquiry.

The nerves of the face are, first, the *trigeminus*, or the 5th of Willis, and that familiarly called the *portio dura* of the seventh, but which, in this paper, will be called *the respiratory nerve of the face.*

Of the trigeminus, or fifth pair.

In all animals that have a stomach, with palpi or tentacula to embrace their food, the rudiments of this nerve may be perceived; and always in the *vermes*, that part of their nervous system is most easily discerned, which surrounds the œsophagus near the mouth. If a feeler of any kind project from the head of an animal, be it the antenna of the lobster or the trunk of an elephant, it is a branch of this nerve, which supplies sensibility to the member. * But this is only if it be a simple organ of

* The branches of the fifth pair enter the roots of the whiskers of the cat kind, they being feelers. The following is from a paper by Mr. Shaw :—

" In the cat, and in the hare, the branches of the fifth pass not only to the muscles, but also into the whiskers; while the branches of the facial respiratory nerve go past the hairs, and enter into the muscles, moving the tip of the nostril. It is rather difficult to demonstrate the feeling, and is not in its office connected with respiration.

From the nerve that comes off from the anterior ganglion of the leech, and which supplies its mouth, we may trace up through the gradations of animals a nerve of taste and manducation, until we arrive at the complete distribution of the fifth, or trigeminus in man. (See Plate III., in which there are its three grand divisions to the face.) Here

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nerves going into the bulb of the hair in these smaller animals, but it is easily done in the phoca. A preparation illustrative of this fact was shown to me some years ago in Amsterdam, by professor Vrolich; and in the first number of the *Journal de Physiologie Expérimentale*, by M. Magendie, there is an account of "les Nerfs qui se portent aux moustaches du Phoque," by M. Andral. This fact of anatomy, which has been denied by some, is farther demonstrated by the dissection of those animals which have tufts of hair, or whiskers over the eye. In the American squirrel, I have traced the branches of the first division of the fifth into the bulbs of the hairs over its eyebrow."

in the highest link, as in the lowest, the nerve is subservient to the same functions. It is the nerve of taste, and of the salivary glands; of the muscles of the jaws, and of common sensibility. This nerve comes off from the base of the brain in so peculiar a situation, that it alone, of all the nerves of the head, receives roots both from the medullary process of the cerebrum and of the cerebellum. A ganglion is formed upon it near its origin, though some of its filaments pass on without entering into the ganglion. Before passing out of the skull, the nerve splits into three great divisions, which are sent to the face, jaws, and tongue. Its branches go minutely into the skin, and enter into all the muscles, and they are especially profuse to the lips. *

* For the further elucidation of the function of the fifth nerve, see the paper on the Eye, and the Conclusion.

Of the respiratory nerve of the face, being that which is called portio dura of the seventh. *

This nerve does not exist, except where there is some consent of motions established betwixt the face and the respiratory organs; and this is the reason of its circuitous and prolonged course. In fishes, this nerve, instead of being distributed forward to the face, passes backward to the muscles of the gills. In fact, there is, properly, no *portio dura* of the seventh in fishes, the nerve resembling it being a branch of the *par vagum*. A short description of this nerve in the human body, will be necessary to our enquiry.

The respiratory nerve of the face arises

* *Portio dura nervi acustici. Sympatheticus parvus* by Winslow, *Faciale* by Vicq. d'Azyr.

from the superior and lateral part of the *medulla oblongata*, close to the *nodus cerebri*, and exactly where the *crus cerebelli* joins the *medulla oblongata*. The other respiratory nerves, which form so distinguished a part of the nervous system, arise in a line with the roots of this.

The nerve, passing into the internal auditory foramen, is here embraced by the *portio mollis*; but it separates from it, and is received into an appropriate canal of the temporal bone. A little farther on, and while within the temporal bone, two cords of communication are formed with the branches of the fifth nerve, or *trigeminus*. One of these is called Vidian nerve, and the other *corda tympani*. By these communications, nerves go in both directions; branches of the seventh are sent to the muscles at the back of the palate; while branches of the fifth nerve (and also of the sympathetic nerve) are brought into the interior of the ear.

By the second of these communications, the *corda tympani*, [which joins the lingual branch of the fifth, just where that nerve is passing by the side of the *levator* and *circumflexus palati*,] the branches of this respiratory nerve have access to the *velum palati* and its muscles.

The respiratory nerve of the face, emerging through the stylomastoid foramen, divides into many branches, and these diverging, spread to all the side of the face. First, a branch is sent to the muscles of the outward ear; another is sent, under the angle of the jaw, to the muscles of the throat. The principal nerve then passes through the parotid gland, and comes upon the face. Here the branches continue to scatter, to go upwards upon the temple, and downwards upon the side of the neck, forming on the neck a superficial plexus. The principal branches, however, go forward to the muscles of the forehead and eyelids; a branch called superior facial is sent to the muscles of the cheek and the side of the nose; while an inferior facial branch is given to the angle of the mouth, and the muscles which concentrate there.

In this extensive distribution, the nerve penetrates to all the muscles of the face: muscles, supplied also with the branches of the fifth pair. I am not so certain whether its branches penetrate to the skin, so as to accompany the minute vessels of the cheek.

The descending or inferior divisions, which go under the lower jaw, and to the superficial muscles of the throat and neck, are connected with branches of the spinal nerves, and with the respiratory nerves, as may be seen in Plate III.

Its structure.

When we minutely observe the texture of the respiratory nerve of the face, we find it to correspond with the structure of the *par vagum*, and to differ from that of the *trigeminus*. The filaments of this nerve have a very close texture, like a minute plexus. The fifth, compared to it, has large free round filaments, with less intricacy in their texture.

The proportion of the facial respiratory nerve to the fifth is greater in man than in any other animal. If we descend to the next link in the chain of beings (the monkey), we shall find the proportion of it to be much diminished, and that of the fifth increased. The distribution of the nerve is more complicated in the monkey than in the dog, its intricacy being apparently in proportion to the number of the muscles of expression. From the lion, the dog, and cat, we descend to the horse, ass, and cow; in these animals there is a marked difference in the distribution of the nerve, from that of either the monkey or the dog, for, excepting a few branches, which pass to the muscles of the external ear, and to the eyelid, the whole of the respiratory nerve is confined to the muscles of the nostrils and side of the mouth, while in the carnivorous tribes it is spread in great profusion over the cheeks and side of the neck.

There are, however, some varieties in the classes of graminivorous animals. In the gazelle, sheep, and deer, the distribution of the nerve is still more simple than in the horse; while in the camel it is more profuse, and is, in this respect, intermediate between that of the carnivorous and the graminivorous animals. The expression of the enraged camel is sufficiently ferocious, and the manner in which he shows his tusks, when dying, is very similar to that of a carnivorous creature.

If we were barely to consider this distribution of the *portio dura* of the seventh, unbiassed by theory or opinion, we should be forced to conclude, that it is not alone sufficient to supply any one part with nervous power, for every one of its branches is joined by divisions of the fifth. The question then naturally arises, whether these nerves perform the same function? whether they furnish a double supply of the same property or endowment, or whether they do not perform different offices? Having taken all the assistance that the knowledge of the human structure and comparative anatomy afford, we are prepared to decide the matter by experiment.

Experiments on the nerves of the face.

An ass being thrown, and its nostrils confined for a few seconds, so as to make it pant and forcibly dilate the nostrils at each inspiration, the portio dura was divided on one side of the head; the motion of the nostril of the same side instantly ceased, while the other nostril continued to expand and contract in unison with the motions of the chest.

On the division of the nerve, the animal gave no sign of pain; there was no struggle nor effort made when it was cut across.

The animal being untied, and corn and hay given to him, he ate without the slightest impediment.*

An ass being tied and thrown, the superior maxillary branch of the fifth nerve was exposed. Touching this nerve gave acute pain. It was divided, but no change took place in the motion of the nostril; the cartilages continued to expand regularly in time with the other parts which combine in the act of respiration; but the side of the lip was observed to hang low, and it was dragged to the other side. The same branch of the fifth was divided on the op-

* The unwillingness to make more experiments than appeared necessary to warrant the conclusion which I wished to force attention to, viz. the difference of the fifth and the *portio dura* of the seventh, prevented me, for a time, from seeing the full importance of this nerve. Had the same nerve of the opposite side been cut, the motion would have been obviously defective.

posite side, and the animal let loose. He could no longer pick up his corn; the power of elevating and projecting the lip, as in gathering food, appeared lost. To open the lips the animal pressed the mouth against the ground, and at length licked the oats from the ground with his tongue. The loss of motion of the lips in eating was so obvious, that it was thought a useless cruelty to cut the other branches of the fifth.*

The experiment of cutting the respiratory nerve of the face, or *portio dura*, gave so little pain, that it was several times repeated on the ass and dog, and uniformly with the same effect. The side of the face remained at rest and placid, during the

* What I attributed to the effect of loss of motion by the division of the fifth, was, in fact, produced by loss of sensation, as will be shown below.

highest excitement of the other parts of the respiratory organs.

When the ass, on which the respiratory nerve of the face had been cut, was killed, which was done by bleeding, an unexpected opportunity was offered of ascertaining its influence, by the negation of its powers on the side of the face where it was cut across.

When an animal becomes insensible from loss of blood, the impression at the heart extends its influence in violent convulsions over all the muscles of respiration; not only is the air drawn into the chest with sudden and powerful effort, but at the same instant the muscles of the mouth, nostrils, and eyelids, and all the side of the face, are in a violent state of spasm. In the ass, where the respiratory nerve of the face had been cut, the most remarkable contrast was exhibited in the two sides of its face; for whilst the one side was in universal and powerful contraction, the other, where the nerve was divided, remained quite placid.

From these facts we are entitled to conclude, that the *portio dura* of the seventh is the respiratory nerve of the face; that the motions of the lips, the nostrils, and the velum palati are governed by its influence, when the muscles of these parts are in associated action with the other organs of respiration. These passages to the lungs are membranous tubes, moved by muscles, which serve to expand and widen them, so that the air may freely enter into the lungs. It is obvious that, to produce this, these muscles must have a consent with the other muscles of respiration, and move simultaneously with them; and this is effected through the respiratory nerve of the face.

It shall be proved in the sequel, that the throat, neck, shoulders, and chest, have similar nerves to this, similar in structure and function, and that these unite all the extended apparatus of breathing and speaking.

The actions of sneezing and coughing are entirely confined to the influence of the respiratory nerves. When carbonate of ammonia was put to the nostrils of the ass whose respiratory nerve had been cut, that side of the nose and face where the nerves were entire, was curled up with the peculiar expression of sneezing; but on the other side, where the nerve was divided, the face remained quite relaxed, although the branches of the fifth pair and the sympathetic were entire. The respiratory nerve of one side of the face of a dog being cut, the same effect was produced; the action of sneezing was entirely confined to one side of the face.

These last experiments show, that the peculiar expression in sneezing results from an impression on the respiratory nerves, and that the muscles of the face are drawn into sympathy solely by the influence of the respiratory nerve of the face.

There is no part of the nervous system where the anatomy has been more negligently consulted in forming our physiological opinions, than in what regards the office of the sympathetic nerve. The connections of this nerve, or rather system of nerves, being universal, it has been supposed that it was the cord through which the relations of the eye, nose, face, throat, diaphragm, &c., were established, and especially in expression; whereas the combination is effected solely through those nerves which, from their grand or leading function, I have called the respiratory nerves.

It has been presumed, that the act of smiling is peculiar to the human countenance, and that in no other creature can there arise that state of enjoyment which produces this distinguishing character of the human face, the expression of benevolence, or of the enjoyment of the ridiculous. But every one must have observed how near the approach is to this expression, in a dog, when he fawns on his master, and leaps and twists his body and wags his tail, while, at the same time, he turns out the edge of the lips as like a laugh as his organs can express. When the respiratory nerve on one side of the dog's head was cut across, this motion of the lips no longer took place, although it was still observable on the other side, where the nerve was entire.

On cutting the respiratory nerve on one side of the face of a monkey, the very peculiar activity of his features on that side ceased altogether. The timid motions of his eyelids and eyebrows were lost, and he could not wink on that side; and his lips were drawn to the other side, like a paralytic drunkard, whenever he showed his teeth in rage.

We have proofs equal to experiments, that in the human face the actions of the muscles which produce smiling and laughing, are a consequence of the influence of this respiratory nerve. A man had the trunk of the respiratory nerve of the face injured by a suppuration which took place anterior to the ear, and through which the nerve passed in its course to the face. It was observed, that in smiling and laughing, his mouth was drawn in a very remarkable manner to the opposite side. The attempt to whistle was attended with a ludicrous distortion of the lips; when he took snuff and sneezed, the side where the suppuration had affected the nerve remained placid, while the opposite side exhibited the usual distortion.

Thus, it appears, that whenever the action of any of the muscles of the face is associated with the act of breathing, it is performed through the operation of this nerve. I cut a tumour from before the ear of a coachman: a branch of the nerve which goes to the angle of the mouth was divided. Some time after he returned to thank me for ridding him of a formidable disease, but complained that he could not whistle to his horses.

A question having arisen, whether or not the fifth nerve was a muscular nerve at all, an experiment decided that question. On exciting the root of the fifth in an ass recently killed, the jaws were made to snap violently; and on dividing the fifth in another ass the jaw fell down, the muscle being incapable of closing the jaw. This corresponds with the symptoms of disease. We find paralysis of the muscles of the face without paralysis of the muscles of the jaw. Thomas Barret, a patient in the hospital, has his mouth drawn to the left ear, and the eyelids of the right side remain open; but the temporal and masseter muscles retain their power.

Thus it appears that the *portio dura* of the seventh nerve is the principal muscular nerve of the face; that it supplies the muscles of the cheek, the lips, the nostrils, and the eyelids; that is, that it is the nerve which orders all those actions which are in the remotest connexion with the act of respiration. It is possible that those relations may not be apparent at first, but in the prosecution of this subject we shall discover the reasons of those links by which the respiratory organs are combined with the actions of the features.

Of the function of the Trigeminus, or fifth nerve, as illustrated by these experiments.

We have seen that when the fifth nerve, the nerve of mastication and sensation, was cut in an ass, the animal could no longer gather his food. In the individual whose face was paralyzed on one side during the excited state of the respiratory organs, there could be observed no debility or paralysis in the same muscles when he took a morsel into his mouth, and began to chew.

By an experiment made on the 16th of March, it was found, that, on cutting the infra-orbitary branch of the fifth nerve on the left side, and the *portio dura*, or respiratory, on the right side of an ass, the sensibility to pain on the right side, where the *portio dura* of the seventh nerve was cut, remained entire, while that of the left side was completely destroyed by the division of the fifth. It was also apparent in this experiment, as in the others, that there was the most marked difference in the sufferings of the animal, when these nerves were cut across. The cutting of the fifth nerve gave pain in a degree corresponding with our notions of the sensibility of nerves; but in cutting the *portio dura*, it was not evident that the animal suffered pain at all.

Independently of the difference of sensibility in these nerves, there was exhibited, in all these experiments, a wide distinction in their powers of exciting the muscles. The slightest touch on the portio dura, or respiratory nerve, convulsed the muscles of the face, whilst the animal gave no sign of pain. By means of the branches of the fifth nerve, it was more difficult to produce any degree of action in the muscles, although, as I have said, touching the nerve gave great pain.

I divided the branch of the fifth pair, which goes to the forehead, in a man, at his urgent request, on account of the *tic doulourewx:* there followed no paralysis of the muscles of the eyebrow; but in an individual where an ulcer and abscess seated anterior to the tube of the ear affected the superior branch of the respiratory nerve, the eyebrow fell low, and did not follow the other when the features were animated by discourse or emotion.

Facts multiply upon us daily, if our attention be kept awake by a knowledge of the anatomy of these nerves. An unfortunate man was brought into the hospital who had put a pistol loaded with small shot to his right ear. It tore off the ear and opened a ragged wound behind the upright part of his jaw; dissection afterwards showed, that the branches of the *portio dura*, or respiratory nerve of the face, which go to the cheek and nose and mouth, were destroyed, the branches ascending to the eyelids were left entire. The shot had entered by the meatus externus, and had broken up the thin portion of the bone betwixt the tympanum and the cavity of the skull. Notwithstanding the shot was found sticking in the dura mater, under the projection of the wing of the sphenoid bone, the divisions of the fifth nerve were entire and unhurt. Why, we may ask, may not such a wound be taken as an experiment? If it be rudely made, yet we have the advantage of human testimony. The report during life has this passage: "There is no want of sensibility in the face, or lips, or tongue; but he cannot draw his mouth to the right side, though he can to the left." —"The motion of the right eyelid is entire."

Thus experiments and occurrences in practice leave no doubt as to the distinct offices of the two nerves of the face. There is an obscurity in their office as regards the action of mastication.

The following circumstance occurred to a very learned and ingenious gentleman. Suffering under the pangs of toothache, he took the sudden resolution of having his tooth drawn, and by an unexperienced hand; a grinder of the lower jaw was extracted. On putting a tumbler of water to his lips, he said, Why have you given me a broken glass? but he found presently that the glass was entire, but that he had lost the sensation of one half of his lower lip. He thought that he put half a glass to his lips, because the lip had been deprived of sensation in one half of its extent. He retained the power of moving the lip, but not of feeling with the lip: and now, after some years, he does not know when a portion of food, or a drop hangs on that side of the lip, although there be not the slightest impediment in its motions.

This circumstance is explained on reference to the plate, for there is a branch of the fifth nerve called *mandibulo-labralis*, coming through the jaw to be given to the lip. This nerve was undoubtedly hurt where it takes its course in the jaw under the roots of the teeth, and the consequence was the loss of sensation in the one half of the lip which is supplied by it. It is equally important in this investigation to notice, that although the sensibility of the lip was destroyed by the injury of the branch of the fifth, the motion of the lip remained entire through the operation of the portio dura.

These facts regarding the nerves of the lips are of difficult explanation, until we consider what is necessary to the simple act of feeding; when a horse gathers the oats from the hand or from the ground, he must feel the food, which is the office of the branches of the fifth; he must move his lips under the direction of that feeling, or he cannot gather it. It was accordingly discovered by experiment, that whether the seventh or the fifth were cut, if the operation were done on both sides of the face, the creature was deprived of the power of feeding, but from different causes; for in the first experiment it was owing to the loss of motion, and in the second to the loss of sensation.

I am unable to decide whether or not the muscular branches of the fifth nerve go exclusively to the muscles of the jaws. I have found in an individual, that, when the cheeks and lips were twisted by paralysis, he possessed the power of holding with his lips in a manner that indicated a power independent of the seventh. But that the whole sensibility of the head and face depends on the fifth pair, there is every possible proof.*

* Mr. Shaw in a paper on this subject says, "In the case of a little girl, the consequence of disease of the

It will be asked, why a nerve called *respiratory*, should go to the ear and the eye? First, let us enquire, does it belong to the frame of animal bodies that there shall be in them indications of passion? If it be admitted that this is the case, we here

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right *portio dura* is very striking. When she laughs heartily, the right cheek and the same side of the mouth are unmoved, while the muscles of the left side are convulsed with laughter.

"If told to laugh with the right side, she raises the angle of the mouth, but by an action which is evidently regulated by the fifth pair. This attempt to laugh gives a peculiar droll expression to her face." But before we decide on this matter, we must determine whether or not even the *portio dura* of the seventh nerve may not lose one faculty and retain another. I suspect that the influence of passion, as this of smiling or laughing, is lost in consequence of affections that do not destroy the entire power of the nerve.

I have observed in one patient the motions of the eyelids lost, while those of the cheek remained; in another the motions of the cheek lost, while those of the eyelids were entire. These symptoms still tend to show that one function of the *portio dura* may be lost without the other.

learn in addition, that as the *portio dura* is the nerve of respiration, so is it the grand nerve of expression, not only in man, but in brutes also. All that excitement seen in a dog's head, his eyes, his ears, when fighting, disappears, if this nerve be cut. The respiratory nerve being cut across in a terrier, the side of the face was deprived of all expression, whether he was made to crouch, or to face an opponent and snarl. When another dog was brought near, and he began to snarl and expose his teeth, the face, which was balanced before, became twisted to one side, to that side where the nerve was entire; and the eyelids being, in this state of excitement, very differently affected, presented a sinister and ludicrous expression.

On cutting the respiratory nerve of the face in the carnivorous animals, it did not appear that the action of feeding was left so entire as in the graminivorous animals. This gave me reason to reflect on the different natures of the two classes. The beast of prey procures his food under the influence of a blood-thirsty appetite, and suffers a universal excitement; he holds and rends his prey; and especially in the larger animals of this class, the action of feeding is accompanied with horrific sounds of enjoyment: in short, with a highly excited state of the organs of respiration. In the graminivorous animals, the act of feeding is a simple and unimpassioned exercise of the organs of mastication.*

* But this not proving a satisfactory solution of the difference, and the statement of the fifth being a muscular nerve being doubted, (the author's discoveries being turned in argument against him,) further experiments were continued, and the fact was found to be as stated above, — that the sensibility enjoyed through the one nerve, and the muscularity through the other, were,

The author hopes that these experiments will be deemed conclusive; yet it is a pleasanter mode of investigation to have recourse to comparative anatomy. There is only one additional instance of this kind that he will offer. It has been already stated that when a feeler, or antenna, is examined, if it be simply for sensation, one nerve only runs along it. It was suggested to him, that if this theory were true, the trunk of the elephant being hollow, and connected with respiration, it should have two nerves; whereas, in the observations of Cuvier, it was stated to have only one.

Mr. Shaw had an opportunity of dissecting the trunk of an elephant. He says, " From the great power which the elephant

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in all animals which respire by lungs, equally necessary to the act of feeding.

" has over its trunk I was certain that " there must be large nerves running to " it, similar to those which supply the fin- " gers in man; but as the proboscis forms " an important part of the respiratory sys- " tem of this animal, I thought in the " dissection of it there would be the most " distinct proof of the accuracy or fallacy of " Mr. Bell's opinions on the subject of the " *portio dura.*

" The trunk was found to be supplied " not only by branches of the fifth pair, as " described by Cuvier, but also by a very " large branch from the *portio dura* of the " seventh pair.

" The *portio dura* in this elephant was " found emerging from the parotid gland, " as in other mammalia. It gave off some " descending branches to the neck, but

" passed from behind the jaw to the pro-
" boscis, almost as an entire nerve, and of
" the size of the sciatic nerve in man: in
" its course it had only given some small
" branches to the muscles of the eye, to
" those of the ear, and to a small muscle
" which corresponds with the platysma.
" Before it passed into the substance of the
" proboscis, it united with the second divi-
" sion of the fifth pair, which comes for-
" ward from the infra-orbital hole, in two
" large branches. The two nerves being
" then closely united, passed between the
" layers of the muscles, which form the
" greater mass of the trunk. The *portio*
" *dura* became quickly diminished in size,
" as it gave off its branches in great pro-
" fusion to the muscles: but the fifth was
" continued down, as a very large nerve, to
" nearly the extremity of the trunk; in
" this respect resembling the nerves to the

" fingers in man. On making sections of
" the proboscis, near its extremity, a great
" number of these nerves were seen in its
" substance.

" A few branches of the *portio dura* ran
" to the valvular apparatus in the upper
" part of the trunk; but this peculiar
" structure was supplied principally by a
" branch from the fifth pair, which winded
" round under the orbit."

Having brought this investigation to a conclusion, some, perhaps, fatigued by its details, may ask to what does this discussion lead?

Were we to enquire no farther, and to rest content with the inference, that the two sets of nerves distributed to the face have distinct functions; even this must prove useful both to the surgeon and physician. To the surgeon it must be useful, in performing operations on the face, as well as in observing the symptoms of disease. If we have to plan an incision on the face, we must take especial care to avoid cutting the branches of the seventh nerve, for then there will be paralysis of the muscles supplied by that nerve. Whereas, if we divide the fifth nerve, though there may be more pain during the operation, and a defect of sensibility following it, no unseemly distortion will be produced. To produce paralysis as a consequence of an operation which was meant to remove deformity, is a considerable mistake; but even worse consequences may result from an ignorance of the distinct nature of these nerves; if, trusting to the eyelids being supplied by the branches of the fifth nerve, a surgeon, in opening an abscess or cutting out a tumour, should divide the division of the seventh which goes to the eyelids, the consequence would be very unfortunate. The eyelids thenceforward would stand apart, the eye would be permanently uncovered, and the cornea become opaque, and the vision of the eye be lost.

By a knowledge of the distinct functions of the nerves of the face, combined with a knowledge of their roots or origins in the brain, we become better able to comprehend symptoms when they are consequent on disease in the bones, or in the base of the brain, or result from injury to the skull or brain, as in the case of gun-shot.

To the physician the facts ascertained in this paper must also be important; he will be better able to distinguish between that paralysis which proceeds from the brain, and that partial affection of the muscles of the face, when, from a less alarming cause, they have lost the controlling influence of the respiratory nerve. How often have I seen a gland affecting a branch of the portio dura mistaken for a disease in the brain itself, because it was not known that, although the fifth nerve was free, the pressure on the seventh nerve was sufficient to paralyze the muscles of the side of the face. The disease of the bone at one time affecting the fifth nerve, and producing excessive pain of the face without paralysis; at another, affecting the seventh nerve, and inducing paralysis without pain, are now phenomena accounted for.

Cases of partial paralysis must be familiar to every medical observer. It is very frequent for young people to have what is vulgarly called a blight; by which is meant, a slight palsy of the muscles on one side of the face, and which the physician knows is not formidable. Inflammations of glands seated behind the angle of the jaw will sometimes produce this; before these observations, it would have been said, that paralysis could not be so produced, because the parts are plentifully supplied by the branches of the fifth nerve. All such affections of the respiratory nerve will now be more easily detected; the patient has a command over the muscles of the face, he can close the lips, and the features are duly balanced; but the slightest smile is immediately attended with distortion, and in laughing and crying the paralysis becomes quite distinct.

The fact appears to be, that the respiratory motions of the face produced by the influence of this nerve are subject to derangement from slight causes; by causes which do not influence the general nervous system, nor even the other functions of the seventh nerve. We shall see in the next paper, that this character belongs to other branches of the same system in their distribution to the trunk.

The knowledge of the sources of expression teaches us to be more minute observers. The author had lately to watch the breathing of an infant which had been several times restored from a state of insensibility. At length the general powers fell low, without any returning fit; insensibility and loss of motion stole over the frame; all but the actions excited by the respiratory nerves ceased; then each act of respiration was attended with a twitching of the muscles of the *ala nasi*, and of that muscle of the cheek which makes the dimple in smiling. It was then evident that the child could not recover; that all but the system of respiratory nerves had lost their powers.

There are conditions of the lungs, when the patient is in great danger, and yet the inflammation is not marked by the usual signs of pain and difficult motion of the chest. We shall see nothing but the twitching of those muscles of the face, which are animated by the respiratory nerve. We see a certain unusual dilatation of the nostrils, and a constrained motion of the lips, which with the change of voice is just sufficient to give alarm, and indicate the patient's condition. This is a state of the lungs very often produced after severe accidents, as gun-shot wounds, and after great surgical operations.

These circumstances are stated to prove, that the subject of expression is not foreign to medical studies; and certainly, by attention to the action of the muscles of the face, we shall find the views drawn here from the anatomy farther countenanced. We learn that smiling is an affection of the nerve of respiration on the muscles of the face, and that when laughter shakes the sides, it is only an extended and more convulsive action of the muscles produced by the same class of nerves. When to the paleness and coldness and inanimation of grief, there is added the convulsive sob and the catching of the throat, and the twitching of the lips and nostrils, we discover the same class of nerves to be affected, which, in crying, are only more obviously in operation, producing more violent contractions.

In all the intermediate emotions between these extremes, the varieties of expression in the face are produced by the opposition of the two powers affecting the same muscles; the one is a voluntary power, by which we restrain the features and conceal emotion; the other is an involuntary power, which cannot be always controlled, but which will sometimes have sway and mingle its influence.*

CONCLUSION.

When the account of the nerves of the throat, neck, and chest, shall be laid before the Royal Society, as those of the face have now been, and when a comparison shall be made of the varieties in nerves correspond-

* This subject of expression is treated by the author in a distinct volume of essays.

ing with the changes in the mechanism of respiration in different animals, a juster estimate may be formed of the importance of these observations. Then the same distinctions of structure and function, which are made manifest in the nerves of the face, will be observed in nerves which take an extensive course through the body. We shall be able to distinguish and separate the nerves of respiration, amidst the apparent intricacy of the general system. By cutting across these nerves of respiration, we shall find it possible successively to stop the motions of the several parts, which unite in the act of respiration; not only to stop the motion of the diaphragm, but the motions of the side, of the shoulder, of the larynx or the pharynx, by cutting their respective respiratory nerves. When this is done, they will be left in the exercise of their other functions through their other nerves, and still alive to other excitements, and capable of performing the voluntary motions, though dead to the influence of the heart and lungs.

By thus distinguishing the nerves of respiration, and as it were separating them from the others, we reduce the remaining part of the nervous system to comparative simplicity. The seeming intricacy in the branching of the nerves, their convergence to certain organs from different origins, their re-union and divergence, instead of being a source of confusion, becomes a subject of the highest interest. The reunion and crossing of nerves we now ascertain to be for the purpose of associating the muscles into different classes, for combining them in subserviency to different organs, and placing them under the guidance of a sensibility more certain in its operation than the will.

By these observations, simplicity and arrangement are now the characters of our anatomical demonstrations, and a better foundation is afforded for discovering and comprehending the symptoms of disease.

EXPLANATION OF PLATE III.

Being a View of the Nerves of the Head.

In this plate the two distinct classes of nerves which go to the face are represented; the one to bestow sensibility, and the other for motion, and particularly for the motions of speaking and expression, that is, the motions connected with the respiratory organs.

The nerves on the side of the neck are also represented. These I have discovered to be double nerves, performing two functions; they controul the muscular frame, and bestow sensibility on the skin. Besides these regular spinal nerves, which are for the common endowments, the nerves of the throat are represented. These latter nerves are the chords of sympathy which connect the motions of the neck and throat with the motions of the nostrils and lips, not merely in swallowing and during excited respiration, but in the expression of passion, &c.

A. The respiratory nerve of the face, or according to authors, the portio dura of the seventh nerve.
a. Branches ascending to the temple and side of the head.
b. Branches which supply the eye-lids.
c. Branches going to the muscles which move the nostrils.
d. Branches going down upon the side of the neck and throat.
e. Superficial cervical plexus.
ff. Connections formed with the cervical nerves.
g. A nerve to the muscles on the back of the ear.
B. The eighth nerve, par vagum, or grand respiratory nerve.

C. The superior respiratory nerve or spinal accessory nerve.
D. Ninth nerve or lingualis.
E. Diaphragmatic nerve.
F. Sympathetic nerve.
G. Laryngeal nerve.
H. Recurrent laryngeal nerve.
I. Glosso pharyngeal nerve.
I. Frontal nerve, a branch of the fifth.
II. Superior maxillary nerve, a branch of the fifth.
III. Mandibula labralis, a branch of the fifth.
IV. Temporal branches of the second division of the fifth.
V. The suboccipital nerve. The first of the spine.
VI. The second spinal nerve.
VII. VIII. Spinal nerves.

I shall add here some familiar instances and cases to show the importance of the knowledge of the nerves of the face in the investigation of disease.

" *J. Richardson*, October, 1820.—On first looking at this man, there does not appear to be any thing unusual in the state of his face; but the moment he speaks or smiles, the mouth is drawn to the left side. When he laughs, the distortion is increased; and when he sneezes, the difference between the two sides is quite extraordinary.

"On holding ammonia to his nose, it was observed that he could not inhale freely with the right nostril; and, on examining the state of the muscles, when the act of sneezing was excited by the ammonia snuffed up by the left nostril, it was found, that not only those of the right side of the nose and mouth, but also of the eyelids, were passive, while all the muscles of the left side were in full action. When he blew, or attempted to whistle, the air escaped by the right angle of the mouth, the right buccinator not at all corresponding in action with the muscle of the left side, nor with that of the muscles of the chest and neck, by which the air was expelled. The sensibility of the paralysed cheek was equal to that of the other side, and he could close his jaws with equal force on both sides."

The early history of the case, according to the account given by the patient's friends, was this: —

"He was seized with a severe pain under the ear, and in a short time became so delirious, and his face so distorted, that the people in whose house he lodged, supposing him to be mad from brain fever, carried him to the parish work-house. There he lay until his friends discovered him, and brought him into the hospital. It was then found, that the phrensy which had led the people of the lodging-house to suppose that he was mad, was only a high state of delirium, in consequence of a severe attack of cynanche parotidea; indeed, the inflammation had run so high, that an abscess formed and burst under the ear. When the swelling subsided the degree of paralysis was very observable.

The delirium and the paralysis of the face naturally led the medical gentlemen, who first saw this patient, to suppose that the symptoms were caused by an affection of the brain. Luckily, the treatment generally followed in cases of phrenitis, was best adapted for the particular affection which had caused both the delirium and the paralysis. The portio dura being engaged in the inflammation under the ear, was the true cause of the paralysis.

For the next case I am indebted to a physician in Worcester: —

Worcester, July 25, 1824.

" Dear Sir,

" My acquaintance with the nature of your late researches upon the functions of the nerves induces me to send you the following case:—

" A young gentleman, aged 14, residing in the village of Kempsey, in this county, was observed by his family to have the expression of his countenance much altered. As long as the features were quiet nothing unusual was observable in the countenance; but as soon as any passion was excited the expression of the face was so different to what was natural to him, that his brothers and others of the family complained of his 'making faces at them.' He, in fact, only smiled, laughed, or frowned upon the left side of his face, the muscles of the right side remaining inactive; and, as they passively yielded to the contraction of the muscles of the left side, the countenance, of course, was much distorted whenever these were called into action. He lost the power of whistling, and, for the same reason, of blowing, and was unable to close his right eye. The sensibility of the right side was as perfect as that of the left. He was quite unconscious of any change in himself, and was not at all aware of the distortion of his countenance when he smiled, &c. This affection did not occur suddenly, but seemed gradually to increase, and became so evident in the course of a week, as to induce the father of the young man to send for his apothecary, Mr. Bick, of Kempsey. When Mr. B. saw him he found the symptoms as above stated; but upon examining the right side of the face more minutely he discovered a fulness immediately beneath the right ear, produced by a hard, fixed, and indolent tumour, lying between the ramus of the lower jaw and the mastoid process of the temporal bone.

"He ordered him some aperient medicine, and directed the tumour to be rubbed with camphorated oil. In a fortnight the tumour disappeared, and with it, gradually, the paralysis of the muscles of that side of the face. It is a fortnight since Mr. Bick first saw him, and he has now recovered every power, excepting that of blowing or whistling. I saw him several times during the progress of his cure. It appears to me that the portio dura of the seventn pair was, in this case, injured by the pressure of an enlarged gland soon after its emergence from the stylo-mastoid foramen, and that upon the removal of the pressure its functions were restored.

"I remain, dear sir,

"Your obedient servant,

"JONAS MALDEN, M. D."

The danger to which the eye is exposed by paralysis of the portio dura, or by any operation on the face, in which its functions are not attended to, is well illustrated by the following case:—

"This poor man, about nineteen years ago, was attacked by a severe pain accompanied with discharge from the right ear. After a paroxysm severer than usual, he found, on getting up one morning, that the right side of his face was paralytic. His present condition, and the description which he gives of the progress of the symptoms, prove that the same results followed this paralysis, as in the instances already related. But what this poor fellow particularly laments is, that since the day he was first attacked, he has not been able to close his right eye; and well he may regret this, for the constant exposure of the eye to the light and dust has been the cause of many attacks of inflammation, and, consequently, of opacity of the cornea, so that the vision is now entirely lost. This, I fear, will often occur in similar cases, for I have observed that the eye has always become inflamed in those animals in which the portio dura has been cut. It is worthy of remark, that the inflammation has been more severe in the dog and in the ass than in the monkey. One great source of the increase of the inflammation is the purulent secretion from the conjunctiva; this the monkey wiped away with his hand; but it lodged between the eyelids of the dog and of the ass, so as to form an additional source of irritation."

The ultimate effects of the loss of power over the muscles of the face, in consequence of an affection of the portio dura, are shown in the following extract:—

"A most remarkable appearance in the face of Garrity is the wasting of all those muscles of the face which are subservient to respiration and expression. His cheek is so thin that when he speaks it flaps about as if it were only skin, and the corrugator supercilii and occipito-frontalis, which are principally muscles of expression, are so wasted, that we might, at first sight, suppose they had been removed by operation, and that now the bones were only covered by skin. There can be little doubt that the wasting of these muscles has been in consequence of their long inactivity; since the masseter and temporalis muscles of the same side, which retain their office, are not at all diminished in size, being as large as those of the opposite side."

A curious example of a contrary effect produced on the growth of the muscles of respiration and expression, by an injury of the portio dura, was afforded in an experiment made upon a young dog. After the nerve was cut he was taught to snarl whenever a stick was held out to him; this being often repeated, the muscles of the side upon which the nerve was entire, became very strong, while those on the paralysed side rather diminished than increased as the dog grew older. In a few months the one side of the face was much larger than the other. Every day we see similar results following palsy of the muscles of the limbs.

Many instances will now occur to my reader of cases where the paralysis of the face, consequent on a local affection of the portio dura, has been mistaken for an attack of apoplexy, and the patient treated accordingly. In one case the patient, after having undergone the discipline of bleeding, purging, and starving, and after having had his head shaved and blistered, was suddenly cured by the bursting of an abscess in his ear.

In another case, the disease commenced with a violent pain below the ear, and in a short time one side of his face became paralysed. For this paralytic affection he consulted many eminent men. The first plan of treatment was bleeding, blistering, and starving, the disease being supposed to have its origin in the brain; but as he got rather worse than better under this treatment, he was put upon a course of mercury, which was carried to such an extent, that he lost several of his teeth. After he recovered from the bad effects of the mercury, he was recommended to attend only to the state of his digestive organs. But the blue pill had no effect upon the distortion. The last advice which this gentleman received was to wear an issue in his neck; with this, however, he has not complied, as he feared it would, like some of the other remedies, have the effect of rendering him more uncomfortable.

A great many cases, somewhat similar, have been presented to me by my pupils; I will add only three other instances, two of which are from papers by Mr. Shaw.

The first regards a patient who had suffered an attack of common apoplexy; it may be offered in example of that train of symptoms which is consequent on an affection of the original or symmetrical system of nerves, and as distinguishable from those which follow an affection of the superadded class. The second is of a man, in whom both the portio dura and the fifth had been injured by a blow; and the third is of a patient in whom both these nerves seem to have been affected by a disease within the skull.

J. Cooper. — This man's general appearance is completely that of an old paralytic, but the distortion of his face is more remarkable than usual, in consequence of the right or paralyzed side being marked with a red blotch.

The arm and leg of the same side are nearly powerless, his intellects are much impaired, and his memory gone. The history of his case was given very clearly by his wife ; according to her account, her husband was, for the first time, attacked with apoplexy about seven years ago ; from this attack he gradually recovered, but at the end of twelve months he was a second time seized, and, since that period, he has had two distinct attacks every year ; for the last two or three years he has been nearly in the same condition as at present.

State of the cheeks and mouth. — When he is made to laugh, the right cheek rises in the same degree with the left ; when he blows (he always bursts into a laugh when asked to whistle), the buccinator of the right cheek is in as much action as on the other side. When his nose is irritated by snuffing ammonia, the actions of the muscles, preparatory to sneezing, are equal on both sides of the face. These phenomena prove that the muscles of both cheeks are perfect in their actions as far as they are regulated by the respiratory nerve; they stand in contrast with the state of the same muscles in the cases related, pages 143 and 146, when the act of sneezing was excited.

The next inquiry related to the influence of the branches of the fifth pair of nerves.

The right cheek, and the right side of the mouth, fall lower than the left. When a piece of bread was put between the teeth and right cheek, the patient could not push it from its place, but was obliged to pick it out with his tongue. The saliva constantly flows from the right side of his mouth, and when drinking, part of the fluid escapes from the same side. The loss of the sensibility of the orbicularis oris was farther shown by the inability to hold a pencil, or a tobacco-pipe, in the right side of his mouth.

The comparative degree of sensibility in the two cheeks was next examined; when he was pricked on the right cheek with a needle he seemed perfectly insensible, even though I drew blood, but on giving the least prick to the left side, he immediately started; the same difference in the degree of sensibility was observable in pulling a hair from each whisker (the sensibility of the right and left limb corresponded with that of the cheeks).

On putting hartshorn to the right nostril he inhaled it as well as with the left, and immediately all the symptoms observable in a person about to sneeze were presented.* As the nose was turned up, and the alæ nasi of both sides were equally in action, this was a sufficient proof of the state of the paralyzed side being here very different from the condition described in the foregoing cases. The power of the fifth over the nose was tried: by tickling the inside of the right nostril no effect was produced; but on tickling the left nostril the symptoms of sneezing were again evident.

The motion of the eye was perfect.

He could close the eyelid of the paralyzed side as well as the other; and when his nose was irritated by the hartshorn, or when he laughed, the orbicularis oculi and

* The apparent sensibility of the nostril over which the fifth had lost its influence may be explained, by supposing that the fumes of the ammonia passed by the posterior nares to the other nostril, and thus caused sneezing.

corrugator supercilii were in complete action, so that there was not here that heaviness in the expression of the upper part of the face, which is so remarkable in paralytic persons. Here, then, was proof that those actions of the eyebrows which we find to be deficient, when the portio dura is affected, are, in a case of common palsy, left entire; indeed, we may have daily opportunities, while walking in the streets, of observing that patients with palsy of one side of the body, have no difficulty in closing the eyelids.

In the next case, both systems of nerves seem to have been affected.

Phipps, a bricklayer, on the 1st of September 1821, fell from a scaffold thirty feet high. His right clavicle was broken, his right loin and hip were much bruised, and he received a severe contusion on the head, the marks of which were particularly observable in a puffiness behind the right ear, and in bleeding from the same ear and from the nose.

He was in a state of stupor when brought into the hospital, but from this he recovered in the course of the day. For the two or three first days he appeared to suffer only from the effects of *concussion*, never having any of those symptoms which are generally attributed to *compression*. On the fourth day it was observed, that the angle of the mouth was drawn rather to one side, and there was also a degree of inequality in the contraction of the pupils.

On the sixth day it was remarked, that while he was asleep, the right eye was more than half open, while the left was closed.

The notes of the case are very full up to the 24th of September, and show that the patient had, during the interval, gone through the common series of symptoms which accompany that slight inflammation of the brain which is often the consequence of concussion.

On the 1st of October, he was made an out-patient, his face being, at this time, very much distorted.

The general appearance of his face at this time was that of a man who has suffered paralysis from apoplexy. But it was further remarkable, that when he spoke or laughed, the distortion was much increased, the mouth being pulled more to the left side, than I ever saw in any other patient.

The following are the notes that were taken at this time. There appears to be total paralysis of the muscles of the right side of the face. When he smiles or laughs they are passive, while those of the left are regularly in action. If he attempts to whistle, he cannot close his lips sufficiently; when he blows, the right cheek is dilated, but passive like a distended bladder ; he can smoke, by putting the pipe into the left side of his mouth; he throws the smoke out of the right side, but in doing this, the action is evidently confined to the muscles of the left cheek.

The cheek and mouth hang down, as in the common case of hemiplegia — he cannot by a voluntary act move his cheeks; when a piece of bread is put between the cheek and teeth of the right side, he cannot push it out with the buccinator, but picks it out with his tongue. He cannot hold his pipe or my pencil with the right side of his lips. These may be considered as sufficient proofs of the total paralysis of the muscles of the face.

The difference of the sensibility in the two cheeks was very distinct. When a hair of the right whisker was pulled, he was not conscious of pain; but he started immediately on pulling one from the left. When his cheeks were pricked with a needle, his expression was — " I feel you push against the right side, but in the left you prick me." When he brought his jaws forcibly together, he said he was not conscious of striking his teeth on the right side, though he felt them most distinctly on the left. On examining the state of the nose, we found that it was impossible to excite the muscles of the right nostril to any action.

The state of the right eyelids and eye-brow corresponded with those of patients who have paralysis of the portio dura, for both the orbicularis oculi and corrugator supercilii were so completely paralytic, that he could neither close his eye, nor knit his brow on the right side.

On examining how far the branch of the 5th, which passes to the eye and eye-lids, was affected, we found that the symptoms did not exactly correspond with those observed in the parts regulated by the other divisions of the 5th pair, and particularly in the degree of sensibility; for when a hair was pulled from each temple, or from the eye-brows, the pain felt in the two sides was nearly the same; neither the temporalis, nor masseter muscles of this side were paralyzed. The motions of the eye-ball were so far perfect, that he could follow an object carried before him, but he could not direct both eyes truly, he saw double. The contraction and dilatation of the pupil of the right eye, were much the same as in the other eye.

He can put out the tongue and move it in every direction with the greatest ease: the motions are all apparently correct and natural; he can throw a morsel from one side of the mouth to the other, and towards the throat, and he can pick it out from between his cheek and teeth.

These observations led us to conclude, that not only the motor linguæ, or ninth nerve, but also the glosso pharyngæal were perfect.

This case differs from the common examples of partial paralysis of the face, not only in there being evident marks of paralysis while the muscles of the face are at rest, but in the sensibility of the skin of the same side being in a great measure destroyed. It differs also from the case of hemiplegia.

The first difference which we observe in it, from the case of common hemiplegia, is, that the paralysis is confined to the face. Secondly, that the paralysis is on the same side with that on which the head is injured. Thirdly, that the palsy is more evident, when the patient is made to sneeze or laugh. From these circumstances, we may conclude that there was here an injury of the skull affecting both the fifth and the seventh nerve.

"*James Galland,* ætat. 26.—Was admitted into the Middlesex Hospital, April

15. 1823. His mouth and left cheek are twisted towards the right side: the whole surface of the left side of his face is insensible: he has not the power of moving the eye of that side, and it has lately become inflamed; he complains of a deep pain in the temple of the same side.

"His trade has been so profitable as to enable him to live in a most dissipated manner during the last five years. He has frequently strolled about the streets at night in a state of drunkenness, and has for three weeks never thrown off his clothes, and has been seldom in bed. He has been twice affected with syphilis; he was confined by his first attack for eighteen months, during which time he was under the influence of mercury. After regaining his health, he frequently experienced a pricking pain in his left eye and temple, so severe as to prevent his reading, especially by candle-light. About twelve months ago he was knocked down: he fell on the back of his head, and wounded the occipital artery; he thinks that he has never been quite well since that time. On the 13th of October, last year, one of his comrades noticed to him that his mouth was drawn to one side; this induced him for the first time to observe in a looking glass the condition of his face. He tried to spit, and observed that his saliva, instead of passing through the centre, was squirted out of the right corner of his mouth, which was contracted. His lips were in other respects perfectly natural, being possessed of sensibility and the power of motion. He could then likewise close the eyelids of the left eye, but to do this he required to shut the other eye also.

" On the following morning he was conscious of a peculiar numbness above the left eye. This numbness imperceptibly and gradually spread over the left cheek, and at the same time affected the external and internal surfaces of almost all that side of his head. He lost the sense of taste on the left side of his tongue, and in little more than a fortnight he became deaf in the left ear. Now he complains principally of the inflamed condition of the left eye, (which commenced about ten days ago), and of the pain in his left temple.

" The above circumstances he himself could relate distinctly; the following is an account of his present condition, April 20.

" The left side of his face is drawn towards the right, and is slightly œdematous. The left nostril is collapsed, and does not expand during breathing. The mouth is distorted towards the right side. When he speaks the two sides of his face are distinctly marked by a line of division; the action of the muscles of the mouth and nostrils, on the right side, being quite distinct, while those on the left are motionless. He has lost all power over the left eyelids; until lately, he could elevate his upper eyelid, although, since the time of his first attack, he has always experienced a certain difficulty in closing it. At present the eye-lid hangs down flaccid and shut; he is unable to press the eye-lids together.

"The sensibility to touch is gone on the greater part of the left side of his head and face, and this insensibility extends to the vertex of the head. The surfaces of the conjunctiva and eyelids are also completely insensible, yet the eye is inflamed and ulcerated; the left side of the nose, the cheek, the upper and lower lips are all equally insensible; but he is sensible when touched upon the left side, below the under jaw, and even over the lower jaw itself, as high as the inferior part of the lower lip. The external ear, and likewise the back part of his head, nearly as high up as the vertex, retain their natural sensibility.

"The internal surfaces of the left nostril, and of the mouth and gums on the same side are insensible to touch; and he has neither the sense of taste or common feeling in this side of the tongue; in consequence of this, portions of food have sometimes lodged within the left side of his mouth, without his being aware of their presence, until they became actually putrid.

"The power of moving his tongue is quite perfect: if at rest, it lies in its natural position within the mouth; nor is it dragged towards either side when he is told to move it. Being tickled with a probe on the left side of the root of his tongue, the sensation of nausea and the effort of retching are produced as on the opposite side. He can open and close his jaws; yet it can be observed, when he is made to clench his teeth, or to bite forcibly, that the masseter and temporal muscles of the right side are hard, rigid, and strongly in action, while the same muscles belonging to the opposite side are totally different in that respect, for they feel soft and flaccid.

"With regard to his left eye, it has been already noted, that it is deprived of common sensibility, and that he has no power of shutting or raising his eyelid. Besides these, he possesses no command over the eye-ball: his eye remains fixed and motionless, and directed straight forwards when he attempts to turn it towards objects. No motion exists in the pupil when a light is presented to the eye. He has the power of vision, although he sees dimly; this is, probably, on account of the eye being inflamed and the cornea ulcerated and opaque. When both his eyes are closed, he is sensible of a red light in the left eye, while nothing is visible in the right one. *

"He was questioned as to the period when he observed that he had lost the power of directing the left eye to objects, but he was unable to inform us, because he imagined always that that eye was as much in motion as the other.

* See remark on this in the first paper on the motions of the eye.

"August 1824.—This man is still alive, several of the symptoms of paralysis both of the portio dura and of the fifth are become more indistinct; he has regained a little power over the motions of the eye-lids, and of some of the muscles of the face, and the surfaces are endowed with a slight degree of sensibility."

In this case we may observe, that the symptoms show the affection to be limited to the seventh and fifth nerves of the left side, and they best correspond with the supposition, that a disease of the bone, or membranes, has affected these nerves in their course, and is gradually extending forward to the nerves of the orbit.

I shall close the narration of these cases by the statement of a circumstance which occurred to me a few years ago:—

A gentleman, in the vigour of life, came into my room to consult me, having the most remarkable distortion of countenance I had ever seen. He proceeded to state to me what he conceived to be the cause of this paralytic affection of one side of his face: he had been knocked down by a blow upon the ear, and had remained a whole night insensible, with bleeding from the ear, from which time his features had been thus drawn to the opposite side. I thought I should give him comfort by stating to him that this was a paralysis attributable to the injury of the bone, and that, as it had not proceeded from an apoplectic tendency, there was no danger of a future attack or of increase of the paralysis. But this was not what he expected from me; he had consulted my brother, then at Rome, and he had proposed to cure him by an operation.

I was quite at a loss to conceive what operation his ingenuity had contrived to relieve so remarkable a deformity. This gentleman mentioned that it had been intended to make three small incisions on different parts of his face, so as to restore the balance of his features: and he was obviously disappointed in finding me less intelligent, or less able than he had expected, and we parted.

On reflecting on the conversation of this gentleman, it occurred to me, that my brother, believing that the paralysis had arisen from an injury of the fifth nerve, had proposed to restore the features to an equilibrium by dividing the branches of the same nerve on the opposite side; trusting, no doubt, to the features being still animated by the seventh pair of nerves. A singular consequence would have resulted from such an operation. The features would have remained drawn to the same side as before, and he would have been deprived of all sensibility of that side! If it was designed to have cut the *portio dura* of the side contracted, a more unhappy consequence would have resulted; for he could never afterwards have spoken, or even have kept his lips to his teeth, or retained the saliva. The features of both sides would have fallen in relaxation, and the eye would have remained uncovered, and he would have lost his sight by the inflammation and opacity consequent on its continual exposure!

It must, indeed, appear a singular circumstance now, that so many surgeons were cutting the branches of the fifth pair of nerves for the tic doloreux, without being led to enquire more particularly into the functions of the several nerves of the face. We see how near my brother's ingenuity was leading him wrong, from having often cut the fifth pair without producing horrible distortion. And I believe that the very same mistake led an honourable baronet to say that I had not cut the frontal branch of the fifth pair of nerves on the face of a nobleman, when I had only cut that branch without interfering with the branches of the *portio dura*, and, consequently, without producing the slightest effect on the muscles of the eyebrow. All these circumstances, I hope, tend to enforce the importance of anatomy.

OF

THE NERVES

WHICH

ASSOCIATE THE MUSCLES OF THE CHEST,

IN THE ACTIONS OF

BREATHING, SPEAKING, AND EXPRESSION:

BEING

A CONTINUATION OF THE PAPER ON THE STRUCTURE AND FUNCTIONS OF THE NERVES.

From the Philosophical Transactions, 1822.

OF THE NERVES

WHICH

ASSOCIATE THE MUSCLES OF THE CHEST, &c.

[*Read before the Royal Society, May* 2. 1822.]

In a former paper an examination was made of the nerves of the face; that part of the system was taken, as proving, in a manner the least liable to exception, that two sets of nerves, hitherto undistinguished, possessed distinct powers; and that very different effects were produced when the muscles and integuments were deprived of the controuling influence of the one or of the other of these nerves. In that paper it was shown, that parts remote in situation were yet united by the closest sympathy with the lungs. That by a division of one nerve, these organs could be severed from the other parts of the apparatus of respiration; and though rendered dead to the influence of the heart and lungs, were yet possessed of their other properties, such as sensibility and voluntary motion.

In the present paper it is proposed to prosecute this subject, by tracing the nerves which influence the motions of the trunk of the body in respiration, and to subject them to a similar enquiry.

It is an encouraging circumstance to the author of this paper, and may incline the Society to bear with the detail into which it will be necessary to enter, that already practical benefits have arisen from the former paper; that the views presented there, as connected with general science, being carried into practice, have enabled the physician to make more accurate distinctions of disease, and the surgeon, in removing deformity, to avoid producing distortion.*

Of the Motions of the Thorax, as affording a Key to the Intricacy of its Nerves.

We have seen the necessity of considering all the functions and relations of a part of the animal machine, the nerves of which we propose to distinguish according to their uses; and this is even more necessary with respect to the thorax than the face. This will be evident, if we make a mere catalogue of the uses of this compages of

* This is alluding to the operations performed on the face and neck.

bones and muscles. Besides affording support and protection to the heart and lungs, and the viscera of the higher region of the abdomen, the thorax performs these offices: —

1. It alternately opposes and yields to the weight of the atmosphere, thus producing respiration.

2. In addition to the uniform motion of the chest in breathing, there is the occasional increase and agitation commensurate to the excited state of the animal frame, when additional muscles are brought into action.

3. There is the exertion of the respiratory apparatus in natural voice, and in articulate language.

4. Through the nerves and muscles employed in respiration are also exhibited the emotions and passions of the mind.

5. The organs of the sense of smelling, and particularly the muscles which move the cartilages of the nose, are, in their exercise, as necessarily joined to the act of inspiration, as those of speech are to the act of expiration.

6. The acts of coughing, sneezing, vomiting, and yawning, belong to this system of parts.

7. The powers of the arms in voluntary exertion are in a great measure dependent upon the expansion of the thorax; so that the act of inspiration is always combined with sudden and powerful exertion. The more, indeed, we attend to the motions of the frame, whether in efforts of strength, or in the act of respiration, the more remarkable will the unexpected combinations of the muscles appear.

It is only when we are made sensible of the extent of the respiratory actions, and that they, in effect, extend over the whole face, and neck, and trunk, that we can comprehend how the mechanism of the thorax, or rather of the respiratory apparatus generally, affects the arrangement of the whole nervous system. Wherever, in examining the comparative anatomy of animals, we find ribs rising and falling by respiratory muscles, we have a *medulla spinalis*, and the distinction of *cerebrum* and *cerebellum*. And experiment and observation prove, that the seat of that power which controuls the extended act of respiration is in the lateral portions of the *medulla oblongata*, from which it is continued through certain respiratory nerves which pass out from the neck, and also downwards, by corresponding columns of the spinal marrow, to the intercostal nerves.

Origins of the Respiratory Nerves.

The nerves on which the associated actions of respiration depend, and which have been proved to belong to this system by direct experiment and the induction from anatomy, arise very nearly together. Their origins are not in a bundle, or fasciculus, but in a line or series, and from a distinct column of the spinal marrow. Behind the *corpus olivare*, and anterior to that process which descends from the cerebellum, the *corpus restiforme*, a convex strip of medullary matter, may be observed; and this convexity, or fasciculus, or *virga*, may be traced down the spinal marrow, betwixt the sulci, which give rise to the anterior and posterior roots of the spinal nerves.

This portion of medullary matter is narrow above where the *pons Varolii* overhangs it. It expands as it descends ; opposite to the lower part of the *corpus olivare* it has reached its utmost convexity, after which it contracts a little, and is continued down the lateral part of the spinal marrow.

From this track of medullary matter on the side of the *medulla oblongata*, arise in succession, from above downwards, the fourth nerve; the *portio dura* of the seventh nerve; the *glosso-pharyngeus* nerve; the nerve of the *par vagum;* the *nervus ad par vagum accessorius;* the *phrenic*, and the *external* respiratory nerves.

It is probable that the branches of the intercostal and lumbar nerves, which influence the intercostal muscles and the muscles of the abdomen in the act of respiration, are derived from the continuation of the same cord or slip of medullary matter. Nor will it escape observation, that the nerves called phrenic and external respiratory, though coming out with the cervical nerves, do, in all probability, take their origin from the same portion of the medulla spinalis with the accessory nerve.

The intercostal nerves, by their relations with the medulla oblongata, are equal to the performance of respiration, as it regards the office of the lungs; but they are not adequate to those additional functions which are, in a manner, imposed upon the respiratory apparatus, when they are brought to combine in other offices.

Of the Muscles of the Trunk, which are brought in aid of the common Respiratory Muscles.

If we look upon the frame of the body for the purpose of determining which are the muscles best calculated to assist in the motions of the chest, when there is an increased or excited action, we shall have little difficulty in distinguishing them, and we shall have as little hesitation in assigning a use to the nerves which supply these muscles exclusively. For these nerves have the same origin: they take an intricate course, threading and passing betwixt other nerves and other muscles, to be entirely given to the muscles which heave the chest.

In this enquiry it is necessary to observe, that the life of animals is protected by a particular sense which gives rise to an instinctive motion of drawing the breath, and by which the chest is suddenly and powerfully expanded on exertion or alarm. The start, on sudden alarm, is accompanied with a rapid expansion and rising of the chest, and the voice, at such a moment, is produced by suddenly inhaling, and not by expiration; and this expansion of the chest combines with the preparation for flight or defence, since the extension of the muscles lying on the breast and back is produced by this motion, and since they are thereby rendered more powerful in their influence upon the arms or anterior extremities. It cannot escape observation, that oppression and difficulty of breathing is exhibited in gasping and forcible inspiration, in drawing the breath, not in throwing it out.

Accordingly, when we examine the trunk of the human body, we have no difficulty in distinguishing the muscles most capable of raising the chest; and these, in effect, we see powerfully influenced in deep inspiration, whether the action be voluntary, as in speech, or involuntary, as in the last efforts of life, when sense is lost. They are the mastoid muscle, the trapezius, the serratus magnus, and the diaphragm.

1. *Sterno-cleido-mastoideus.*—This muscle, by its attachment to the sternum or breast bone, raises or heaves the chest; and the operation of this muscle is very evident in all excited states of respiration, in speaking, and still more in singing, coughing, and sneezing. But there is something necessary to the full effect of this muscle on the chest, for otherwise it will be a muscle of the head, and not of the chest.

2. *The trapezius* must fix the head or pull it backwards before the *mastoideus* can act as a respiratory muscle, and how they are combined we shall presently see. The position of the head of the asthmatic, during the fit, as well as the posture of the

wounded or the dying, prove the influence of the upper part of the trapezius in excited respiration.

The trapezius has a still more powerful and important influence in respiration when the action rises above the ordinary condition, and that is by drawing back the scapula, to give the necessary effect to the action of the serratus magnus.

3. The *serratus magnus anticus* being extended over the whole side of the chest, and attached in all the extent from the second to the eighth rib, is very powerful in raising the ribs; but it cannot exert this power, independently of the trapezius, since, without this combination, its force would be exerted in moving the scapula, and not the ribs; unless the scapula be

fixed, or pulled back by the *trapezius*, the *serratus* is not a muscle of respiration.

In this manner do these three powerful muscles hang together in their action, combining with the diaphragm to enlarge the cavity of the chest in all its diameters.

The course of our enquiry leads us to ask, are these muscles privileged above others by any peculiarity of nerves? And the answer is plain: to these muscles alone, are the nerves, which I am about to call respiratory nerves of the chest, distributed.

*Anatomy of the Respiratory Nerves of the Trunk.**

The nerves which give rise to the extraordinary intricacy of this system on the side

* See Plate II.

of the neck, are the spinal accessory nerve, the phrenic nerve, and the external thoracic nerve. By reference to any common book of anatomy, the phrenic nerve (fig. 12. Pl. II.) will be found to have its great root or origin from the fourth cervical nerve; and there joins this, a more slender branch from the third cervical nerve. But, besides these roots, it has connections, which of themselves would mark the relations of the nerve; high in the neck, it is connected with the *nervus vagus* and with the *lingualis medius*, while, at the same time, a branch is given off to the muscles of the larynx. The trunk of the nerve descends into the cavity of the thorax, and gives no branches, until, arriving at the diaphragm, it sends out numerous diverging branches, which are lost in the substance of that muscle.

It has been long known that irritation of this nerve convulses the diaphragm, and that cutting it across paralyses that muscle. These facts, with the consideration of its course, prove it to be a respiratory nerve, and such has been the universal opinion.

But to what purpose should a distinct nerve be sent to the diaphragm, if the other muscles, seated externally, and which are associated in action with the diaphragm, and as important to respiration, were left without a similar tie to unite them with each other, and with the organs of the voice?

The inferior external respiratory nerve of the thorax (fig. 13. Pl. II.) is a counterpart of the internal or phrenic nerve. It comes out from the 4th and 5th cervical nerves, and often it is connected with the phrenic. It diverges somewhat from that nerve, because, instead of descending within the chest, it falls over the ribs, and descends in a distinct flat trunk upon the outside of the chest, to be distributed entirely to the *serratus magnus anticus.* This muscle has nerves from the spinal marrow, because it has to combine in the motions of the frame in locomotion. But the long descending nerve is a respiratory nerve; which we may know from its origin, course, and destination; in its origin and course it is like the diaphragmatic nerve, and in its destination also, since it is given to a muscle necessary to full inspiration.

I come now to the *spinal accessory nerve* (fig. 11. Plate II.),* which is more par-

* *Nervus ad par vagum accessorius.*

ticularly an object in this paper. It is called here the superior respiratory nerve of the trunk. Experiments may take a colour from the preconceived idea, but the accurate investigation of the structure will not deceive us. The author, therefore, entreats attention to the anatomy of this nerve, as leading in the most conclusive manner to a knowledge of its functions.

It arises from the cervical portion of the spinal marrow; but instead of collecting its branches to go out by the side of the vertebræ, like the internal and external respiratory nerves, it shoots upwards through the theca of the spinal marrow, enters the skull, and joins the eighth pair of nerves; from which it has its term of accessory. We see the roots of this nerve as far down as the fourth cervical nerve.* These roots arise neither from the posterior nor the anterior column of the spinal marrow, but betwixt the posterior roots of the cervical nerves and the *ligamentum denticulatum*, and from the *columm of medullary matter* above described. The origins of this nerve come off in one line, and that line is in the direction of the roots of the eighth pair, and of that nerve which has been proved to be the respiratory nerve of the face. In its ascent the accessory nerve is attached to the posterior root of the first cervical nerve.

The nerve having ascended through the *foramen magnum*, passes out from the skull associated with the nerves constituting the *eighth pair*, and in the same sheath with them; they all go out through the *foramen*

* In the ass, its roots are seen to extend much lower down.

lacerum, and by the side of the jugular vein. In this course the accessory nerve divides into two. One of these divisions joins filaments of the *par vagum* (fig. 1. Pl. II.); and these again send nerves to the *glosso-pharyngeal* nerve (fig. 9. Pl. II.); and sometimes a branch may be seen going to the *lingualis medius*. The more exterior division of the accessory nerve descends behind the jugular vein, and comes forward and perforates the mastoid muscle. In its passage through the muscle it sends off branches which course through its substance; and if, as sometimes happens, though rarely, the nerve does not pass through the muscle, these branches are, notwithstanding, invariably given to it.

When the nerve has escaped from the back part of the mastoid muscle, it forms a communication with that branch of the third cervical nerve that ascends behind the muscle; and nearly at the same time it is joined by a branch from the second cervical nerve. The superior respiratory nerve now descends upon the neck, and begins to disperse its branches in regular order to the edge of the trapezius muscle (fig. 11. Pl. II.); four or five branches take their course to that muscle, separate into minute subdivisions, and are lost in its substance. One more considerable division, being the lowest of these, is joined by a long descending branch of the second cervical nerve. Increased by this addition, it descends under the trapezius and behind the clavicle. Following this descending branch, it will be found exclusively attached to the trapezius. Behind the scapula it is again joined by branches from the spinal nerves; and here a sort of imperfect plexus is formed, from which divisions of the nerve, still descending, follow the lower edge of the muscle, and are finally dispersed among its fibres.

This nerve arises from the same column with the respiratory nerves; it takes a most intricate and circuitous passage to form a junction with nerves which we know to belong to that class; it send branches to join the nerves of the tongue and pharynx; it sends branches to the larynx in company with the branches of the *par vagum;* it then crosses the great nerves of the neck, passes under the spinal nerves, goes to no other muscles in its course, but lavishes all its branches on the mastoid and trapezius muscles. To an anatomist it is as plainly set forth as if it were written in our mother tongue, this is *the superior respiratory nerve of the trunk.**

* *Lobstein*, in a dissertation on this nerve, finding the difficulty of accounting for the *nervous fluid* coming by a

Comparative view of these Nerves.

If we examine the *par vagum*, the *portio dura* of the face, the *external thoracic*, the *diaphragmatic*, and the *spinal accessory* nerves, by comparative anatomy, we shall conclude that they are all respiratory nerves, by their accommodating themselves to the form and play of the organs of respiration. In fishes, the respiratory nerve* goes out from the back part of the *medulla oblongata*. When it escapes from the skull it becomes remarkably enlarged, and then disperses its branches to the branchiæ and the stomach. But from the same nerve go

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double passage to the muscle, concludes, *veniet forsan tempus quo ista quæ nunc latent, dies extrahat et longioris ævi diligentia.*

* The nerve which by its subdivision supplies the heart, lungs, and stomach, and the muscles of the gills.

off branches to the muscles moving the gills and operculum, whilst a division of the nerve is prolonged under the lateral line of the body to the tail. It is said, this division sends off no branches, but this is not correct; it gives branches in regular succession to the muscles from the shoulder to the tail. Experiments have been made upon these nerves, but their detail would lead us too far. It is scarcely necessary to add, that there are neither phrenic nor spinal accessory, nor external thoracic nerves in fishes, the order of their muscular system not requiring them. In birds, the structure of the wing, and the absence of the mastoid muscle, render the spinal accessory nerve unnecessary; it is wanting, for the reason, that in the absence of the diaphragm there is no phrenic nerve. Quadrupeds have the three respiratory nerves of the trunk; but even in them there are variations in the muscular frame, which illustrate the appropriation of the nerves. The construction of the neck of the camel is like that of birds; there is a succession of short muscles along the side of the neck, and attached to the vertebræ; but there is no long muscle, like the *sterno-cleido-mastoideus*, contributing to the motion of respiration. There is, accordingly, no spinal accessory nerve in the neck of this animal.

We have a remarkable example of the manner in which these nerves vary in their course of distribution, and yet retain their appropriate functions, in the nerves of the neck of birds. In them, the bill precludes the necessity of the portio dura going forward to the nostrils and lips; the nerve turns backwards, and is given to the neck and throat; and it is particularly worthy of remark, that the action of raising the feathers of the neck, as when the game cock is facing his opponent, is taken away by the division of this nerve. If we compare the anatomy of the facial respiratory nerve, in the various classes of birds, we shall find its distribution to be analogous to that of the same nerve in the different tribes of quadrupeds. In the game cock, a few branches of the nerve pass to the loose skin under the jaw, which is dilated in crowing, the greater number being distributed on the muscles of the neck, which causes the elevation of the feathers when he puts himself in an attitude for fighting. But in the duck, which, when enraged, has little or no power of expression, the same nerve is not larger than a cambric thread, and passes only to the skin under the jaw. *

* These respiratory nerves of the thorax, the diaphragmatic, the superior, and the external thoracic nerve, are

The Functions of these Nerves farther illustrated.

Before having recourse to experiments on brutes, we may observe what takes place in our own bodies. By placing the hand upon the neck, we may be sensible that the mastoid muscle has two motions. The lower extremity of the muscle is fixed when we move the head; but when we use the muscle in inspiration, the head, and consequently the upper extremity of the muscle,

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all nerves of *inspiration*. The act of inspiration is provided for in a more especial manner than the act of expiration. It requires more muscular effort, and is more essential to life. Inspiration is the first act of resuscitated life, the last of exhausted nature, and for this reason the muscles of inspiration are large and powerful, and the nerves in a double order; for not only do the lateral branches of the spinal marrow influence the act of inspiration, but these additional respiratory nerves descend from the upper part of the spinal marrow to the chest, as an additional and especial provision, guarding life.

are fixed. Now, if we endeavour to raise the sternum through the operation of this muscle, we shall find that other muscles are, insensibly to us, brought into action, which have nothing to do with this raising of the sternum. For example, if we strain to raise the lower extremity of the muscle, we shall unavoidably produce an action of the muscles of the nostrils; by which association of actions, we shall discover, that we are using the *mastoideus* as a respiratory muscle. If we reverse the action, and move the upper extremity of the muscle, other muscles will be drawn into co-operation, but they will be such as assist in the motion given to the head. Or we may vary the operation in another way. In snuffing or smelling, if we place the fingers on the portions of the mastoid muscles which are attached to the sternum, we shall find every little motion of the nostrils accompanied with corresponding actions of the sternal portions of the muscles in the neck.

When a man suffers fracture of the spine at the sixth cervical vertebræ, and the marrow is crushed, he continues to breathe by the influence of the three nerves which arise above the injured portion. He inspires with force; but he cannot perform expiration by muscular effort, it is only by the elasticity and gravitation of the parts. He can yawn, for that is an action of drawing the breath; but he cannot sneeze, for that is an action of expelling the breath. But this is a subject so curious in itself, and which has hitherto been considered so carelessly, that I shall reserve it for a distinct dissertation.*

A man having a complete hemiplegia,

* See the observations, p. 221.

the side of his face relaxed, the arm hanging down powerless, and the leg dragged in walking, we were curious to know if the influence pervaded all the nerves of the side, or only the regular or voluntary nerves. Some trouble was taken to make him heave up the shoulder of the debilitated side, but to no purpose. He could only do it by bending the spine to the other side, and as it were weighing up the paralytic shoulder. But on setting him fairly in front, and asking him to make a full inspiration, both shoulders were elevated at the same time that both the nostrils were in motion. The respiratory nerve of the face, and the superior respiratory nerve, were entire in their office; and, although the regular system of nerves refused acting, the *sterno-mastoideus* and the *trapezius* partook of their share in the act of respiration. Seeing that the mastoid muscle has two sets of nerves, that one of these is of the class of voluntary nerves, and the other of respiratory nerves, are we not borne out in concluding, that when the head is moved, being a voluntary act strictly, it is performed through the common class of voluntary nerves? that when the chest is raised, it is an act of respiration, and is effected through those nerves which controul the muscles in respiration?

This conclusion is confirmed by the following experiment. In the ass, there are two muscles which take the office of the mastoid muscle; one is inserted into the jaw, which we may call *sterno-maxillaris*, and the other into the vertebræ, viz. *sterno-vertebralis.* To these the superior respiratory nerve (or spinal accessory) is distributed in its pasage to the trapezius. These muscles are at the same time supplied with numerous nerves directly from the spinal marrow. If we expose the superior respiratory nerve, and then induce excited respiration, so as to bring these muscles into powerful action in combination with the other muscles of respiration, and if, while this action is performed, we divide the nerve, the motion ceases, and the muscle remains relaxed until the animal brings it into action as a voluntary muscle.

An ass being thrown, its phrenic nerves were divided, on which a remarkable heaving of the chest took place. It rose higher, and the margins of the chest were more expanded at each inspiration. There was no particular excitement of the muscles of the neck, shoulder, or throat, at this time; so that to excite the actions of these muscles it was necessary to compress the nostrils. When they began to act with more violence, keeping time with the actions of the other muscles of respiration, the superior respiratory nerve was divided; immediately the action ceased in the muscles attached to the sternum of the side where the nerve was divided, while the corresponding muscles of the other side continued their actions.

After dividing the spinal marrow between the vertebræ of the neck and those of the back, respiration is continued by the diaphragm: which experiment, as it is often mentioned by physiologists, the author has not thought it necessary to repeat, but only to institute the following experiment on an ass. The phrenic nerves being first divided, and then the spinal marrow cut across at the bottom of the cervical vertebræ, respiration was stopped in the chest; but there continued a catching and strong action at regular intervals in the muscles of the nostrils, face, and side of the neck. The main part of the apparatus of respiration was stopped, but these accessory muscles remained animated, and making ineffectual endeavours to perform the respiration. When apparent death had taken place, the ass was re-animated by artificial breathing, and then these muscles on the face and neck were restored to activity, and became subject to regular and successive contractions, as in excited respiration, whilst the chest remained at rest. These actions continued for a short time, and then ceased; but upon artificial respiration being again produced, the same results followed. This was repeated several times, the animal remaining insensible during these experiments.

Upon stimulating the nerves after the death of this animal, it was observed, that the class of respiratory nerves retained their power of exciting their respective muscles into action, long after the other nerves had ceased to exert any power; they were evidently of that class which retain their life the longest.

It is a duty to avoid the unnecessary repetition of experiments, and I have now to make a short statement of facts, resting on the highest authorities: experiments made without reference to the views now presented to the Society.

The division of the recurrent branch of the *par vagum* destroys the voice.*

The division of the laryngeal branch of the *par vagum* stops the consent of motion

* Sectis ambobus nervis recurrentibus vox perit: *Arnemann, Sömmerring, Morgagni.*

between the muscles of the *glottis* and the muscles of the chest.*

The injury or compression of the *par vagum* produces difficulty of breathing.†

By the assistance of these well-known facts, we complete the knowledge of the circle of actions which result from the respiratory nerves.

The *medulla oblongata* and *spinalis* are composed of columns of nervous matter, and from the different powers of the nerves, as they arise from the one or other of these columns, it is proved that they possess distinct properties. In animals that breathe by ribs

* *Le Gallois.*

† Vinculo compressis nervis vagis oriuntur in bestiis spirandi difficultas, surditas, vomitus, corruptio ciborum in ventriculo. *Sömmerring, Haller, Brun de ligaturis nervorum.*

and a numerous class of muscles, and which animals have a spinal marrow, we see that a column of nervous matter is embraced between the anterior and posterior *virgæ* of that body, and that this portion may be traced downwards between the roots of the spinal nerves. From the upper part of this column, where it begins in the *medulla oblongata*, the several nerves proceed which have formed the subject of these papers, and on the influence of which, it has been proved, the motions of respiration principally depend. It is not an extravagant conclusion to say farther, that the power of the regular succession of intercostal and lumbar nerves, as far as they regulate the respiratory actions, proceeds from the connections of the roots of these nerves with this column, which is continued downwards, and which can throughout be distinguished from the rest of the spinal marrow.

We are now enabled to distinguish the influence of the spinal marrow, and its regular succession of nerves, from those which have been traced in these papers. The first are essential to the act of respiration; without them the others are unequal to the task. But on the other hand, although the regular succession of spinal nerves be equal to the raising and depressing the thorax, they are not equal to the full heaving of the chest in animated exertion of the voice. They are not competent to the performance of the motions of the glottis, pharynx, lips, and nostrils, which several parts are necessarily influenced in excited respiration, as well as in the acts of smelling, coughing, sneezing, and speaking: for these, the co-operation of the whole extended class of respiratory nerves is required.

Surveying the complicated machinery which in man is prepared for these various offices, we may reap the benefit of these fatiguing details, in the contemplation of the most interesting phenomena in nature. The relations of the subject may be presented under the heads of pathology, and expression.

On the Actions of Respiration in those who have suffered Fracture of the Spine at the lower Cervical Vertebræ.

When the spinal marrow is crushed at the upper part of the spine, the man dies instantly; but if the spinal marrow be crushed opposite to the lower part of the neck, although the injury be such as to deprive him of all sense and all voluntary motion of the parts below, he continues to breathe.

It has been stated by our first authorities, that a man in these circumstances breathes by his diaphragm, in consequence of the phrenic nerve, which supplies that muscle, taking its origin from the spinal marrow above the part injured. But the observations have been inaccurately made which have led to this opinion. I shall first show how untenable such a supposition is, and then detail the phenomena which attend the fracture of the spine at this part; and, finally, show that other nerves, besides the phrenic, descend from the same source to supply the exterior muscles of the chest, and that it is through their influence the act of respiration is continued.

The diaphragm is that muscular septum which divides the thorax and abdomen, and by the descent of which the depth of the cavities of the chest is increased in inspiration. When it has acted and descended, and the air is admitted into the lungs, that air is again expelled by the re-action of the abdominal muscles. These muscles compress the viscera, and, by pushing them up, raise the relaxed diaphragm, preparing it for another effort of inspiration. Is it not obvious, that if the power of the diaphragm remains entire, and the power of the abdominal muscles be lost, that the respiration must stop? It would be so, were it not that there are other muscles and other nerves no less important than the diaphragm and the phrenic nerves, and which physiologists have not contemplated.

In the first part of this paper it is shown that the *sterno-cleido-mastoideus*, the *trapezius*, and the *serratus magnus*, are muscles calculated, by their combined operation, to raise the chest with great force, and to perform inspiration. It is also shown that the nerves there described as the superior and the external respiratory nerves, take their course exclusively to those muscles which act upon the chest, and that what the phrenic nerves are to the diaphragm, these are to the three great exterior muscles. It is further shown in this paper, that as all these nerves take their origins from the same part of the spinal marrow, they are consequently in the same circumstances as to fracture of the spinal tube. When the spine is fractured at the lower cervical vertebræ, these nerves escape injury, and continue to animate the muscles exterior to the ribs as well as the diaphragm.

The great importance of these exterior nerves and muscles to the continuance of life will be proved by the following cases. I have purposely omitted all the detail of practice, and have taken the symptoms purely in a physiological view, and as if it were an experiment instead of a most afflicting accident to a fellow creature.

Within the space of one month these three instances of fracture of the vertebræ of the neck have occurred in my practice. In one instance, the bones were broken at the lower part of the neck, and the patient lived some days. In the second instance, the vertebræ of the neck were fractured in the middle of the neck, and the man lived half an hour. In the last instance, the uppermost vertebra was fractured, and the death was immediate.

CASE I.

Percy Ward, 29th May. — Charles Osborne, ætat. 26. — On Saturday evening this man was putting pulleys into a window sash when the small steps on which he stood slipped from under him, and he was precipitated through the window into the area, a height of 13 feet. He thinks he fell upon his back; but he is uncertain, as he lay for some time senseless. He lies now in bed, supine and powerless, but describes the part injured to be the spine betwixt the scapulæ. As we desire to have only the essential feature of this case, it is better to say at once, that this was a deception, that he felt the pain of the injury at a point considerably lower than the fracture, and that on his death it was discovered that the arches and bodies of the sixth and seventh cervical vertebræ were broken.

The lower extremities are motionless and insensible. He can raise his shoulders and bend his arm, but over the motion of the hands he has no power.

Another report adds,—his expression is singular; he says he can move his arm by the strength of his shoulders, which is exactly true, for by moving the shoulder he can give a certain rotary motion to the humerus, and, consequently, move the fore-arms when they are bent at the elbow. The skin of the arms, however, retains its sensibility to the point of a pin. The abdominal muscles are relaxed, and the viscera feel flaccid. He can make no effort to expel the urine; his urine is drawn off by the catheter, and his fæces pass involuntarily: there is priapism. When I induce him to attempt an effort and to strain, no change on the abdominal muscles can be felt; there is no firmness or rigidity in them. The integuments of the abdomen and of the chest, as high as the nipples, are insensible.

His breathing is frequent, and at each inspiration the chest is heaved with a short and quick movement; at each expiration the abdomen is protruded with a sudden shock and undulation. The belly, during this effort of breathing, is uniformly soft and full, when drawn in it is by the elevation of the ribs, and when the chest falls it is protruded.

He has been observed to yawn naturally. Query. Can he cough?

An examination has been made to-day to answer this query. When he is asked to cough, he pulls up the ribs and extends the chest, and lets them fall: he coughs, but not strongly: it is obviously by his power of raising the chest and giving elasticity to the ribs, and by the weight of the parts falling, that he is enabled to expel the breath. He cannot divide the expiration into two coughs, nor give two impulses to the air; but each time he coughs the elevation of the chest must precede it.

On spreading the hands and fingers on the side of his chest the action of the serratus muscle could be felt, and also the lower margin of the trapezius muscle was felt to become firm during the act of inspiration, as when he prepared to speak.

Being asked if he had sneezed by any chance, his answer was — "No, sir; I cannot blow my nose." This was not that he could not raise his hand to his head: he was conscious of wanting the power of forcibly expelling the air. Mr. B., taking a handkerchief from a nurse, and holding the patient's nose as a woman does a child's, the patient could not blow the nose; he could not give that sudden impulse of expiration which is necessary.

In one of the reports of this case it was stated that the patient was disturbed by horrible dreams. This is very likely from the respiration being in part obstructed; but I omitted to verify that observation during the patient's life.

It is remarkable in this case, that on feeling his stomach he, of his own accord, marks the difference of sensibility, internal and external. He says he feels internally, but he does not feel on his skin. He feels me when I press the stomach, and has complained of the griping from his medicines.

This man died in the night of the seventh day from the accident. The night nurse gave no particular description of the manner of his death, further than that he seemed to desire to speak and could not: he made attempts to articulate, but could not.

CASE II.

James Saunders, ætat. 45, June 30.— This man fell only four feet, but he fell backwards, and struck his neck against an iron railing. The transverse processes of his fifth and sixth cervical vertebræ were found fractured; and there was diastasis of the articulations between these vertebræ. The body of the sixth vertebra was fractured. The spinous processes, also, of the fourth and fifth vertebræ were found fractured at their bases.

The house surgeon reports of this man, that when he was brought into the hospital he was perfectly sensible; that his face indicated great alarm and anxiety. Every time he drew his breath it was attended with an effort to raise the shoulders, and a contraction of the muscles of the throat: every time he breathed his head appeared to sink beneath his shoulders. On putting his hand on the pit of his stomach no motion of the viscera of the abdomen could be perceived. He had no feeling even in the upper part of his chest: he had feeling on his face and neck, and indistinctly near the collar bone. He had a motion of his hands, a sort of rolling motion, which may have proceeded from the shoulders. When he spoke it was in a tremulous voice, like a man frightened: his voice was weak, but he did not speak in a whisper: the sound of his voice was more like sighing than common breathing. Pulse was felt at his wrist. In ten minutes after he was brought in, half an hour from the time of the accident, he died.

CASE III.

On the following day a man was brought into the hospital dead. He had fallen fifty feet, and had lighted on the ground upon both his shoulders. By the accounts of the men who carried him to the hospital, he appears to have been instantaneously killed. The dissection sufficiently proved that he was killed suddenly. For besides extensive fracture and injury to the lower part of the spine, the atlas and dentata were found likewise fractured. The tooth-like process of the vertebra dentata was broken through just at its base. It was separated completely, and was found embraced by the transverse ligament in its natural situation upon the atlas. The arch of the atlas was partially fractured on each side, and a portion of its body, where the process of the dentata rolls upon it, was also fractured and detached.*

* A young man was brought into the Middlesex Hospital, who had fallen upon his head. He soon recovered, and lay for some time in the hospital without exhibiting a symptom to raise alarm. He had given thanks to the assembled governors of the hospital, and had returned into the ward for his bundle, when, on turning round to bid adieu to the other patients, he fell, and in the instant expired. Upon examining his head, it was found that the margins of the occipital hole had been broken: no doubt it had happened that, in turning his head the pieces were displaced, and closed and crushed the medulla oblongata, as it passes from the skull.

A man was trundling a wheel-barrow in Goodge Street, which is immediately adjoining the Middlesex Hospital: in going from the carriage-way to the flagstones he met the impediment of the curb-stone. He made several efforts to overcome it, and at length drawing back the wheel-barrow he made a push, and succeeded; but the wheel running forward, he fell, and remained motionless. He was taken into the hospital, In the above narratives we have the account of those symptoms which accompany fracture of the cervical vertebræ, and which have hitherto been negligently considered, from an entire want of interest in the subject. It appeared to me very distinctly, that, in the case first described, the man had the power of drawing his breath by muscular exertion; but that the expulsion of the breath was not a muscular effort, but occasioned entirely by the elasticity of the ribs and the gravitation of the parts forci-

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but he was found to be quite dead. The tooth-like process of the second vertebra of the neck had burst from the transverse ligament of the first. The impulse given to the head had done this violence, and had at the same time carried forward the spinal marrow against the process, and on which it was crushed.

These cases occurred before my time, but I have had two instances of sudden death from the dislocation of the atlas from the second vertebra of the neck. In short, the fact is perfectly well ascertained.

bly raised by the action of the muscles. This was evident in the total want of the power to exert the abdominal muscles, or to compress or depress the chest above its condition of rest; in the necessity of raising the chest at the utterance of each word; in the perfect power of yawning, which is a gradual and powerful act of inspiration; in the want of the power of sneezing or blowing the nose, which is a sudden call of the muscles of expiration into action.

The strongest reason of all for this view of the use of these nerves, which I have called respiratory, is, that respiration and the activity of the muscles of the chest did actually continue after the functions of the spinal marrow were destroyed by violence done to the tube, and that there is no other explanation of the fact than this, that those nerves which take their origin from the medulla oblongata and upper part of the spinal marrow, and which descend upon the neck and chest, did continue to animate the sterno-cleido mastoideus and the trapezius, and the muscles of the throat, in the act of inspiration. We have only further to recollect, that it was not the forcible, occasional, and voluntary motions of respiration that were thus preserved, but that by the same means, viz., the superior, the external, and the phrenic nerves, the play of the chest in respiration during sleep was continued.

vid. pag. 223

In the second case, it is clearly proved, both by the symptoms and the dissection of the bones, that the fracture must have affected the roots of the phrenic nerves; and we are at liberty to conclude, that the difference of symptoms, in comparing it with the first case, as well as the shorter period of his sufferings, was owing to this cause.

The manner of breathing was very different, and is described by our house surgeon * in a manner to produce conviction. *His breathing was like sighing;* and at each inspiration his head was drawn betwixt his shoulders. That is to say, that by the loss of the action of the diaphragm the action was thrown on the muscles exercised through the spinal accessory nerve, and this is confirmed by what is said of the want of motion in the viscera of the abdomen; for, as it was proved in the first case, at each contraction of the diaphragm the viscera of the abdomen are propelled outward.

The want or defect of action in the dia-

* Mr. Turner.

phragm, and the action of breathing being circumscribed to the muscles of the neck and shoulders, were undoubtedly the cause of the patient sinking so soon.

In the last case, it appears, the spinal marrow being injured so high up as to destroy the roots of all the respiratory nerves the death was sudden, as in pithing an animal.

When we have ascertained these facts certain queries are naturally suggested. Why should these respiratory nerves, which descend from above upon the thorax, go only to muscles which assist in raising and expanding the chest? Why should the act of inspiration be secured by a double provision of nerves, viz., those which come out from the sides of the spine, and those which descend from the neck, when the act of expiration is provided for solely through the former?

I would offer these reasons: —

First, The act of drawing the breath is the more difficult, and requires the more force; the act of expiration is comparatively easy, being assisted by the weight of the parts incumbent on the ribs as well as the resiliency or elasticity of the ribs themselves.

Second, The act of inspiration is the active state; the condition of expiration is a state of rest.

Third, The inspiration is necessary to life, and must be guarded with more care, and performed with more force than the expiration. In one suffocating, the agony is in elevating the chest and drawing the breath. On the approach of death the inspiration becomes more laboured, that is, the exterior muscles are in violent action; but the act of expiration is an interval of rest.

Fourth, These nerves, which govern the muscles of inspiration, are linked more intimately by sympathy with the state of circulation and respiration; for we see in disease, as in experiments on animals, that when the powers of life have run low, the sympathy is still exerted with such sudden catching of the muscles of inspiration, and with an effort so powerful and unexpected as to startle, while the expiration is soft and without effort. We perceive the same sympathy causing the same sudden and powerful inspirations, and marking the presence of life, when a person is recovering from fainting, or from suspended animation, from whatever cause; as drowning, hæmorrhage, &c. The sudden inspiration is always the first of the renewed actions of life, as it is the last in exhausted nature.

This corresponds with the experiments made on animals. When the sensibility is exhausted in the common spinal nerves, from the ebbing of life, the respiratory nerves on the neck and side of the chest are still capable of exciting the muscles to renewed vibrations; they are the last to die.

These considerations exhibit the importance of the act of inspiration over that of expiration, and prove the necessity for these exterior nerves of respiration.

We have seen by experiments, that the respiratory nerves are distinguished from the other nerves by retaining their power longer: that they are alive to impression, and can be made to produce convulsions in the muscles they supply, after the other nerves are dead to the application of stimuli. In disease, during the oppression of the mental faculties, and on the approach of death, we witness these nerves, and the muscles put into operation by them, continuing their functions, when in other respects the body is dead. This circumstance, so familiar to the medical observer, might have led to the conclusion to which we have arrived, more laboriously, through anatomical investigations; that there are a great many muscles extended over the body, and which perform the common offices under the will, which are occasionally drawn into combination with the muscles of respiration, and are held in relation to the vital functions by a distinct system of nerves, and that these nerves have a centre and a source of power, different from that of the voluntary nerves.

Some further Remarks on the Pathology of the Respiratory System of Nerves.

However strange it may appear to educated and reflecting men, there are not wanting those who say, to what object are all these discoveries tending? what is the good of them? they do not assist us in practice.

I imagine nothing can gratify such persons but what appears in figures on their books. The advance of science is nothing to them; they consider only what is their own relative situation, as to the gains of their profession. But as I am looking to a very different class of readers,—those who are advancing in the study of their profession, and who are anxious to have the means of faithful observation laid in a knowledge of the structure of the human body, I shall proceed to state some instances of the direct use to be made of the knowledge of the nervous system, as set forth in the preceding pages.

When we survey the full extent of the respiratory system of nerves, we are prepared to comprehend its importance to the continuance of life. The infant born without a brain can breathe if the origins of these nerves be entire. Deep wounds of the brain, though eventually fatal, are not necessarily, or instantly so. The man wounded in the spine below the origins of the nerves which we have traced, drags on existence for a few days; but a bruise on the part of the *medulla oblongata*, from which these nerves take their departure, is death in the instant; a breath is not drawn again.

In describing the effects of violence on the medulla oblongata, authors have attributed the sudden death to injury of the roots of the nerves of the par vagum; and yet we have a statement from the same authority, that an animal will survive the division of both nerves of the par vagum. Now that we find that many respiratory nerves depart from the same centre, and go out to all the parts of the muscular frame, which move in respiration, we can better comprehend, how injury of the medulla oblongata suppresses at once the act of respiration in the nostrils, throat, and windpipe, as well as the action of the muscles both without and within the chest; even the expression of the agony of dying is, by the injury of the roots of all these nerves, suddenly interrupted, and actual death follows quickly, owing to the cessation of the respiratory functions.

The first thing that strikes us is the vital character of these nerves, called respiratory; that as they form a system belonging to the heart, lungs, stomach, larynx, throat, and the whole exterior association of muscles of respiration, they must be essential to life, and influenced in all mortal affections; and that, in fact, death cannot take place whilst this division of the nervous system is unchanged or unaffected. On the contrary, the injury to their function is attended with immediate death, and the change takes place with appalling suddenness; not a breath is drawn, nor a word uttered, nor a struggle to indicate pain, nor a feature discomposed.

On the contrary, if other parts of the body are injured by disease or accident, death comes slowly from the rising of iuflammation, or the extension of the influence slowly over the system; at length the respiratory system partakes of the influence, the chest rises higher and more frequently, an alarming symptom, when there is reason to fear approaching dissolution; the throat is then affected; the whole apparatus of respiration is violently agitated; the chest, neck, lips, and cheeks, and eyelids are wrought with terrible convulsions; the breathing is about to stop; the action returns with sudden and startling effort, and then ceases, the patient dying in the state of expiration, the muscles of inspiration being incapable of renewing their effort.

If it be important to know the approach

of danger, and to distinguish betwixt nervous agitation from the formidable symptoms of approaching dissolution, it is necessary to know the causes of these symptoms, otherwise the physician is no better than the nurse.

It must happen that the derangement of one part of this class of important organs must affect the other. The stomach, for example, as the most abused in its office, is daily exhibiting the effect of its close alliance with this system of nerves; and what we learn from this anatomy of the respiratory system, is, that the stomach stands in close connection with the respiratory nerves, and that an irritation on the stomach will have all the effects of an injury immediate upon the lungs.

If the process of digestion should be deranged by exercise while the stomach is full, and if the food, which should be permitted to move gradually from the one extremity of the stomach to the other, is agitated and churned by the exercise of the body; an anxious and breathless condition of the respiration will be the consequence, and an affection of the lungs naturally apprehended.

If there be any affection of the respiratory nerves already existing, the paroxysm of suffering will be brought on or aggravated by the state of the stomach. And now let me add, that as custom adapts the body or its individual parts to any condition, and the functions are performed in circumstances the most adverse by habit, so we may by indulgence let the functions of the stomach gain such a mastery over the other functions of these nerves as to pinion a man down to his chair whenever his stomach is in a state of repletion and the digestion commenced: when, on the contrary, the sailor, the post-boy, like the school-boy, will take his dinner, and be ready for exertion or for play, and the stomach the while will perform its office.

The stomach, heart, and lungs are undoubtedly the seat of that affection which is attended with sudden death; when there are no tokens or symptoms in the agitations of the respiratory organs, the source from which danger is to be most apprehended is the stomach; and founding on the fact expressed above, I have to suggest that it is the duty of the patient to struggle against the increasing influence of the stomach on the condition of the respiratory organs: that the physician has not merely to regulate the stomach as the organs of digestion, but that the patient has to study to preserve his *wind* or freedom of respiration against the prevailing influence of the stomach. If a man, being alarmed at the influence which the state of his digestion is producing daily more and more on the condition of his respiration and the sensation of his chest, if he avoids motion and permits himself to be checked in his exercise, and to become sedentary in his habits, he is running to meet the disease in its attack. On the contrary, he should eat sparingly, and make continual and regular efforts to exercise himself in that manner which produces oppression, until in time he shall overcome it and destroy the disposition.

One of our athletæ out of training is pursy, breathless, and cannot bear the buffets, shocks, and falls to which he is liable in a bruising bout. But by spare and healthful diet, regular severe exercise, mi-

mic combats, in which his breast, belly, and head are repeatedly buffeted, he is at length capable of standing under shocks that would be fatal to a man of equal strength and better constitution, but otherwise unprepared for what he is to undergo. Whether it be an effort of the body, or of the constitutional strength; whether it be an exertion of the head, or hands, or feet, we must come to the full exercise gradually and by slow degrees. Thus I argue the matter with a man whose palpitations are excessive and painful; on every accelerated step he must not altogether avoid the occasion which gives him uneasiness, but by encountering them repeatedly, and by slow degrees, familiarize himself with the exertion.

As these nerves belong to a distinct system, and have a different origin from the nerves of sensibility and common muscular motion, so it is fair to presume that they will occasionally be affected by disease, when the others are left in a natural and healthy condition. But if the natural distinctions of the nerves be negligently considered, the affection of the respiratory nerves must remain obscured. I have already had occasion to remark, that the portio dura, or respiratory nerve of the face, is very subject to derangement, producing partial paralysis, or frequent and spasmodic twitchings of the face. The most frequent defect proceeding from this cause is a rapid and twinkling motion of the eyelid of one side. Sometimes we find the whole of one side of the face subject to contractions, by which the features are drawn towards the ear. This condition of nerves, and consequent spasmodic muscular contractions, sometimes extends to the neck; then we see the head suddenly twitched sideways, at the same moment that the mouth is drawn aside. This is a great deformity; for while the individual is animated and speaking with exertion, he gives those sudden startling motions, opening his mouth and turning it to his shoulder, as if he were catching flies. The neck is twisted, the head bent down, and the mouth turned laterally and opened. These motions must now be attributed to the influence of the respiratory nerves of the face and neck.

But the same class of nerves, in their distribution to the chest, are subject to the same derangement. It is not very uncommon to find the shoulder of a young person falling low, and the appearance of distortion produced by a paralysis of that part of the trapezius muscle which supports the shoulder, and which is supplied by the spinal accessory nerve. This affection forms a parallel with the paralysis of the eyelid and the cheek; and there are not wanting examples of spasmodic affection of the thorax resembling those which I have just noticed on the side of the face and neck. From inattention to the source and nature of the complaint, the following instance is, perhaps, the first which is recorded.

Case of affection of the Respiratory Nerves on the side of the Chest.

Physician's Ward, March 1824.

——— Ætat. 50.—We have not met with so distinct a case of affection of the respiratory nerves of the side as is now presented to us in this patient. The following is a description of his condition :—

If he attempt to lie upon his left side in bed, his head is lifted from the pillow by a rapid succession of contractions of the muscles upon the right side of his neck and right side of his thorax; so that, instead of lying at rest, his head and shoulders are raised from the pillow, and the upper part of his body forms a curve. These contractions are attended with pain, and this pain he cannot otherwise describe than by saying it is like a cramp. When he lies upon his right side he is more at rest, the weight of his head and shoulders counteracting the contraction of the muscles, and keeping him in some degree steady. On being asked whether these contractions disturb him during his sleep, he says he is sensible of their diminution as he is dropping asleep. When he sits up, the head is gradually drawn to the right side, and there is an obvious contraction of the right side of his neck. The sterno-cleido-mastoideus swells, and the trapezius is very distinctly in action; so that the ear is drawn to the shoulder, and the whole body becomes bent so that the head approaches to the side. In this state the pain he suffers is seated behind the mastoid process and at the acromion scapulæ, that is, at the origin and insertion of the sterno-cleido-mastoideus muscle and the insertion of the trapezius. He complains also of the pain and spasm striking from his back to the scrobiculus cordis, as if the diaphragm were affected. He also complains of a pain which is seated in what he calls his "swallow;" that is, a spasmodic affection of the throat accompanies the affection of the external muscles, but he has no impediment in swallowing.

When we say to him, "What, sir, cannot you hold up your head at all?" he makes an exertion and sits upright suppressing his breath. But when he begins to speak, his head begins to descend towards the right side by a succession of little movements, until he is quite bent down as before described. When we attempt to hold his head toward the left side we see the sterno-cleido-mastoideus in violent action on the right side, and the muscles of that side are powerful so as to overcome us. When we hold the head down to the right side, he can pull against us with the muscles of the left side: he has the voluntary power of these entire, but they are not so strong as the muscles of the right side; it appears that by use the muscles of the right side have acquired great volume and strength. At first one might imagine that there was paralysis of the muscles on the left side. But we find that it is not the ordinary contraction of the muscles of the right side of which he complains, but of a violent spasmodic and painful action. That there is no paralysis is obvious from this, that he can move his head to either side, twist round his mouth either to his left or to his right ear, turn his head in any way you choose, and raise his right or his left arm equally, throwing them over his head: all these motions he can perform when the spasm is not upon him. When it does come on, then the muscles of the right side only are affected with contractions, and those of the left side are perfectly relaxed.

Twenty months ago, he says, he was raising a crow-bar and he felt something snap at the upper and back part of his neck, (and he puts his finger to the posterior insertion of the sterno-cleido-mastoid muscle.) He does not say, however, that he felt pain at that time. A month after this he began to have pain, and still he points to the same place, the back part of the mastoid process. The pain has gradually increased with the violence of the contractions; and as we before said, the pain is like that of a cramp, and there is no pain in the intervals of spasmodic action.

Although the source of this complaint be obscure, yet it is an approximation to it to ascertain that the spasmodic contractions are confined to the influence of the respiratory nerves of the trunk of one side. And indeed without the preceding account of the nervous system, the contractions here contemplated must have remained among the very great variety of nervous symptoms which owing to our indolence as yet present to us as mere accidents of nature which it is not expected we should investigate. The man's condition has been produced by the violence of exertion it would appear. We have learned that in violent effort to lift weights the muscles of inspiration are brought into aid of the merely voluntary act; and I have many cases to show that violent exertion or long excitement of nerves, and continued exertion of particular classes of muscles are attended sometimes with paralysis, sometimes with irregular minute spasmodic contractions which are very distressing.

Now we perceive that these nerves of respiration, so peculiar in relation and function, are differently influenced by disease from the other division of the nervous system. We know that their functions are left entire when the voluntary nerves have ceased to act, and they are sometimes strangely disordered, while the mind is entire in all its offices, and the voluntary operations perfect. In tetanus the voluntary nerves are under influence, and the voluntary motions locked up in convulsions; in hydrophobia, on the contrary, the respiratory system is affected; and hence the convulsions of the throat, the paroxysms of suffocation, the speechless agony, and the excess of expression in the whole frame, while the voluntary motions are free.

The confusion between vital and voluntary nerves, the combining the par vagum and sympathetic nerves together, and the exclusion of the *portio dura* of the seventh nerve, the spinal accessory nerve, and the external thoracic nerve, from their natural classification with the diaphragmatic or phrenic, has given rise to very vague theories, and occasioned very inaccurate statements of pathological facts.

The frequency of sudden death, where no corresponding appearances are exhibited in the brain or heart, leads us to consider more attentively the only part of the system through which life can be directly extinguished. In *angina pectoris*, we witness the agony of suffering in this system when the patient survives; and when he dies suddenly, we can imagine it to proceed from an influence extending over these nerves, and interrupting the vital operations. We have seen that a branch of this system may suddenly cease to operate on the corresponding muscles, and that in this way the side of the face may be deprived of all participation in the act of respiration, and all expression be lost. What would result from a more universal defect in the actions of this class of nerves, but sudden death?

The stomach, supplied with the great central nerve of this system, exhibits the most powerful influence on these extended nerves; a blow on the stomach "doubles up" the bruiser, and occasions that gasping and crowing which sufficiently indicates the course of the injury; a little more severe, and the blow is instantly fatal. A man broken on the wheel suffers dreadful blows, and his bones are broken, but life endures; the *coup de grâce* is the blow on the stomach.

The position of the asthmatic shows how this system is affected; whether directly or indirectly, it is not our present business to enquire. He stands stooping forward, resting his arms so as to throw the muscles of the chest into operation upon the ribs. The position of the head and the rigidity of the muscles of the neck, the action of the mastoid muscle, and of the cutaneous muscle, visible in the retraction of the cheeks and mouth, and the inflation of the nostrils, carry us back in review of the nerves and muscles of respiration.

It will now, perhaps, be acknowledged, that the methods of physiologists, in accounting for the combination of parts in the actions of respiration, were very imperfect, or rather altogether erroneous. To account for the convulsion of the diaphragm in sneezing, they were constrained to go a far way about: first, connecting the roots of the phrenic with the sympathetic nerve: bestowing sensibility on the latter, which it does not possess: then, following a remote connection between it and the nerves of the nose; then again, counting the relations between the facial nerve and the third of the neck: they satisfied themselves that they had explained the manner in which the diaphragm became convulsed upon irritating the membrane of the nose. Another misconception was engrafted on the first; they spoke of these actions as convulsive and irregular, which are amongst the most admirable provisions for the protection of life. As to the act of sneezing, like coughing, it is a consequence of an irritation of the extremity of one of the respiratory nerves, whence the whole muscles of respiration are brought into action. That there is nothing accidental, nor of the nature of convulsion, is shown by the admirable adjustment of the muscles to the object. A body irritating the glottis will call into simultaneous action the muscles of respiration, so as to throw out the air with a force capable of removing the offending body. But if the irritation be on the membrane of the nose, the stream of air is directed differently, and, by the action of sneezing, the irritating particles are removed from these surfaces. By the consideration of how many little muscles require adjustment to produce this change in the direction of the stream of air, we may know, that the action is instinctive, ordered with the utmost accuracy, and very different from convulsion.

Of Smelling, as influenced by the Portio Dura of the Seventh Nerve.

In these papers I hope it will be found that I have gone deliberately and diligently about my investigation. It will, I hope, be acknowledged that I have studied the functions of the parts to which the nerves are sent, before I made my experiments or drew my conclusions. Even in the exercise of the sense of smelling, parts are employed, which do not, at first, seem necessary. For the highest enjoyment or exercise of the sense of smelling, it is necessary that the stream of air inhaled through the nostrils should change its direction, and be increased in force. In breathing through the nose, the air is carried directly backward. If the nostrils are expanded in anxious or hurried respiration, the passage is enlarged, and made more direct. But, perhaps, my reader is not aware that in each nostril there are two circular openings, the innermost something more than half an inch within the other. This interior circle expands, and becomes lower when the breath is forcibly drawn into the lungs; but in the act of smelling it is much diminished and elevated. The change in the form and relation of the exterior and internal nostril is performed by the action of the muscles on the cartilages; and the effect of the change is to increase the force of the stream of air, and to direct it up towards the seat of the sense of smelling. In common breathing some part of the effluvia afloat in the atmosphere reaches the seat of the sense; but fully to exercise the sense it is necessary to concentrate and direct the stream of air, as I have described.

It will now be comprehended how the destruction of the *portio dura*, or respiratory nerve of the face, affects the organ of smelling; for if by the injury of that nerve the motion of the muscles of the nostrils be lost, the breath may be drawn into the lungs through the relaxed passage, but it will not be drawn forcibly up towards the seat of the olfactory nerve, nor will the air brush over the surface on which the proper nerve of sense is expanded.

A man being paralytic on one side of the face by the loss of power in the *portio dura*, he was made to smell ammonia: it did not affect the paralytic side, because it was forcibly inhaled into the cells of the nose only on the side where the nostril was movable. On trying the experiment on a dog, in whom the *portio dura* of one side had been cut, the same thing was manifested ; he snuffed it up with the sound side, and showed the natural consequence of the irritation of the membrane ; while he was not similarly affected when the bottle was put to the paralytic nostril.

Unless I had attended to the structure and function of the part, on witnessing these phenomena, I might have conceived that the seventh nerve was the nerve of smelling, like a noted French physiologist, who concluded too hastily that he had discovered the nerve of vision and of smelling in the fifth nerve.

I allude to certain experiments lately performed in London by a distinguished visitor, which afford a proof of the utter impossibility of reasoning correctly on these subjects without the knowledge of the anatomy. The olfactory nerve was destroyed, and ammonia put to the nostrils of the animal, and when the creature sneezed it was a *coup de théâtre!* then the gentlemen congratulated themselves that it was discovered that the first pair of nerves was of no use!! The common irritability of the schneiderian membrane results from the fifth nerve: why does the membrane possess this sensibility, and why is the sensibility joined to the actions of the respiratory system? because these passages must be guarded as the larynx is guarded. When any thing offensive is lodged there it must be removed, and the means nature employs is to drive the air by an instinctive action of the respiratory organs, violently and suddenly, through the nostrils. But what has this to do with smelling? As well might we destroy the olfactory nerve, and wonder that the creature experimented on still coughed when the larynx was tickled.

We have some observations on this subject in Mr. Shaw's paper already quoted. "The effect upon the nostril is the most obvious symptom, when the nerve is cut in the ass. If after having cut the right nerve *(portio dura)*, we hold the nostril for a short time, so as to prevent the animal from breathing, he will, when freed, begin to snort, but with the left nostril only. If we hold carbonate of ammonia to the paralized nostril, he will not be affected; but if it be held to the other, he will snuff it up, and then curl the nostril, and have an expression in the whole of that side of the face, as if he were going to sneeze, while the right side will remain quite unmoved."

The rationale of this is worth attention; by the neglect of it some physiologists and experimenters have appeared to much disadvantage. The act of smelling is not simply the act of drawing the breath; but while the breath is drawn there is a conformity in the motion of the nostrils, by which the air, loaded with the effluvia, is directed to the seat of the olfactory nerve; that is to say, is made to circulate in the higher parts of the cavities of the nose, instead of streaming directly backwards into the posterior nostrils. This was the reason why, on putting the ammonia to the nostril which was still, the creature was not excited, although there had been nothing done to injure the sensibility of that side of the nose. If a man were simply to draw his breath in taking snuff, the powder would be drawn into his fauces and lungs; but to snuff, the point of the nose is drawn down, and the nostrils contracted, and then when the air is inhaled, the snuff rises to the superior cells, and stimulates all the interior of the nostrils. Although by this stimulus he sneezes, the olfactory nerve has nothing to do with it. The luxury is in the stimulus of the respiratory system through the excitement of the membrane, not in the odour as enjoyed by the olfactory nerve. The sensitive branches of the fifth are first excited, then the respiratory system is in a secondary manner affected; and to ascertain whether the mode of communication between the fifth and the respiratory nerves be affected at their roots in the brain, or at their extremities, is a fair question to be determined by experiment or reasoning.

These Respiratory Nerves are Organs of Expression.

We may notice another office of these respiratory nerves; in smiling, laughing, and weeping, the influence is solely propagated through them. The face, we have seen, is dead to all changes of the kind when the nerve of this class which goes to it is destroyed, whether it be by division of the nerve, or from its being surrounded with inflammation or suppuration. When we consider that all the respiratory nerves depart from the same source, and participate in the same functions; and more especially when we see the respiratory organs so very distinctly affected in the conditions of the mind, which give rise to these affections, it is not too much to suppose, that what is proved in regard to one of these nerves, is true of the whole class, and that they alone are influenced in laughter. Physiologists who have not investigated the cause, are yet agreed in describing laughter to be a condition of the respiratory muscles, where the air is drawn in rapidly, and thrown out in short spasmodic motions of these muscles; that crying is nearly the reverse, the inspiration being cut by spasmodic actions of the muscles of inspiration. By these considerations are explained the *subrisus* which arises from abdominal irritation, and the sardonic retraction of the muscles of the face produced by wounds of vital parts, and particularly of the diaphragm. It explains also the successive convulsive lifting of the shoulders in wounds of the diaphragm.

That a system of nerves so intimately combined as this is with the other parts of the general system, should suffer in hysterical disorders, cannot surprise us; and admitting that irritation reaches to the respiratory system, we may perceive how rapidly the change may be produced, from the convulsions of laughter to those of crying; and where, if there be a corresponding condition of the mind, it rather follows than precedes the expression of the frame.

It would have been extraordinary if we had arrived at any satisfactory theory of expression, before it was known through what instruments the mind influenced the body, during emotion or passion. But since we know that the division of the respiratory nerve of the face, deprives an animal of all expression; and that the expressive smile of the human face is lost by an injury of this nerve: since it is equally apparent, that the convulsions of laughter arise from an influence extended over this class of nerves, it comes to be in some sort a duty, in pursuing this matter, to examine farther into the subject of expression. We may be at the same time assured of this, that whatever serves to explain the constant and natural operations of the frame, will also exhibit to us the symptoms of disease with more precision.

In terror, we can readily conceive, why a man stands with eyes intently fixed on the object of his fears: the eyebrows elevated, and the eyeballs largely uncovered; or why, with hesitating and bewildered steps, his eyes are rapidly and wildly in search of something. In this we only perceive the intent application of his mind to the objects of his apprehensions, and its direct influence on the outward organs. But when we observe him farther, there is a spasm on his breast: he cannot breathe freely: the chest remains elevated, and his respiration is short and rapid: there is a gasping and convulsive motion of his lips: a tremor on his hollow cheeks: a gulping and catching of his throat: his heart knocks at his ribs, while yet there is no force in the circulation, the lips and cheeks being ashy pale.

It is obvious, that there is here a reflected influence in operation. The language and sentiments of every people have pointed to the heart, as the seat of passion, and every individual must have felt its truth. For though the heart be not in the proper sense the seat of passion, it is influenced by the conditions of the mind, and from thence its influence is extended through the respiratory organs, so as to mount to the throat, and lips, and cheeks, and account for every movement in passion, which is not explained by the direct influence of the mind upon the features.

So we shall find, if we attend to the expression of grief, that the same phenomena are presented; and we may catalogue them, as it were, anatomically. Imagine the overwhelming influence of grief—the object in the mind has absorbed the powers of the frame; the body is no more regarded, the spirits have left it; it reclines, and the limbs gravitate, the whole body is nerveless and relaxed, and the person scarcely breathes; so far there is no difficulty in comprehending the effect in the cause. But why, at intervals, is there a long drawn sigh, why are the neck and throat convulsed, and whence the quivering and swelling of the lip, why the deadly paleness, and the surface earthy cold; or why does convulsion spread over the frame like a paroxysm of suffocation?

To those I address, it is unnecessary to go farther, than to indicate that the nerves treated of in these papers are the instruments of expression, from the smile upon the infant's cheek to the last agony of life. It is when the strong man is subdued by this mysterious influence of soul on body, and when the passions may be truly said to tear the breast, that we have the most afflicting picture of human frailty, and the most unequivocal proof, that it is the order of functions which we have been considering that is then affected. In the first struggles of the infant to draw breath, in the man recovering from a state of suffocation, and in the agony of passion, when the breast labours from the influence at the heart, the same system of parts is affected, the same nerves, the same muscles, and the symptoms or characters have a strict resemblance.

Having examined the system of nerves and muscles, which are the agents in respiration, in their fullest extent and in all their bearings; having looked at them in their highest state of complication in the human body, and having traced them upwards, from the animals of simple structure, and then by experiment, and in a manner analytically as well as synthetically, their relations become obvious. Instead of one respiratory nerve, the *par vagum*, the nerve so called, is found to be the central one of a system of nerves of great extent. Instead of the relations of the vital organs of circulation and respiration depending on some supposed influence of the sympathetic nerve, they are found to have an appropriate system.

This system of nerves, extricated from the seeming confusion in which it lay hitherto encumbered, is found to be super-added to that of mere feeling and agency, attributes common to all animals: through it we see, engrafted as it were, and super-added to the original nature, higher powers of agency, corresponding to our condition of mental superiority: these are not the organs of breathing merely, but of natural and articulate language also, and adapted to the expression of sentiment, in the workings of the countenance and of the breast, that is by signs, as well as by words. So that the breast becomes the organ of the passions, and bears the same relation to the developement of sentiments, as the organs of the senses do to the ideas of sense.

ON

THE MOTIONS OF THE EYE,

IN ILLUSTRATION OF

THE USES OF THE MUSCLES AND NERVES OF THE ORBIT.

From the Philosophical Transactions, 1823.

ON

THE MOTIONS OF THE EYE, &c.

[*Read before the Royal Society, March* 20. 1823.]

THE object of this paper is to explain the reason of there being six nerves distributed to the eye, and consequently crowded into the narrow space of the orbit.

But before it is possible to assign the uses of these nerves, we must examine the motions of the eye more minutely than has hitherto been done, and try to comprehend the offices to be performed. Much as the eye has been studied, the frame-work which suspends it, and by which it is moved and protected, has not received the attention it deserves. Yet this frame-work, or apparatus, is not less calculated to renew our wonder, than the properties of the organ itself.

It is, therefore, necessary to divide the paper into two parts. *First*, to show the uses of the apparatus which is exterior to the eye-ball; and then, in the *second place*, to consider how the nerves minister to these offices.

PART I.

Of the Muscles and Frame-work which are around the Eye-ball.

Even grave and learned men have eulogized this organ as the most necessary to intellectual enjoyment, and which ranges from the observation of the fixed stars, to that of the expression in the human face.* But this admiration is in part misplaced, if given to the optic nerve and ball of the eye exclusively; since these high endowments belong to the exercise of the whole eye, its exterior apparatus as much as to that nerve which is sensible to the impressions of light. It is to the muscular apparatus, and to the conclusions we are enabled to draw from the consciousness of muscular effort, that we owe that geometrical sense, by which we become acquainted with the form, and magnitude, and distance of objects. We might as well expect to understand the uses of a theodolite, or any complicated instrument for observations, by estimating the optical powers of the glasses, without considering the quadrant, level, or

* Sir Henry Wotton, Dr. Reid, and many others.

plumb-line, as expect to learn the whole powers of the eye by confining our study to the naked ball. I propose to show, that we must distinguish the motions of the eye, according to their objects or uses, whether for the direct purpose of vision, or for the preservation of the organ; that the eye undergoes a revolving motion not hitherto noticed; that it is subject to a state of rest and activity; and that the different conditions of the retina are accompanied by appropriate conditions of the surrounding muscles; that these muscles are to be distinguished into two natural classes; and that in sleep, faintness, and insensibility, the eye-ball is given up to the one, and in watchfulness, and the full exercise of the organ, it is given up to the influence of the other class of muscles: and finally, that the consideration of these natural conditions of the eye explains its changes as symptomatic of disease, or as expressive of passion.

Motions of the Eye-ball and Eye-lids.

We do not reflect on those actions of our frame which are most admirable in themselves, which minister continually to our necessities, and perfect the exercise of our organs, until we be deprived of them; like unnatural children, unconscious or unmindful of indulgence, we feel only the loss of benefits. "With much compassion," says the religious philosopher, "as well as astonishment at the goodness of our loving Creator, have I considered the sad state of a certain gentleman, who, as to the rest, was in pretty good health, but only wanted the use of these two little muscles that serve to lift up the eye-lids, and so had almost lost the use of his sight, being forced, as long as this defect lasted, to shove up his eye-lids with his own hands!"*

Two objects are attained through the motion of the eye-ball. First, the control and direction of the eye to objects; secondly, the preservation of the organ itself, either by withdrawing the surface from injury, or by the removal of what is offensive to it. Without keeping this distinction before us, we shall not easily discover the uses of the parts.

There is a motion of the eye-ball, which, from its rapidity, has escaped observation. At the instant in which the eye-lids are closed, the eye-ball makes a movement which raises the cornea under the upper eye-lid.

* Paley's Natural Theology.

If we fix one eye upon an object, and close the other eye with the finger in such a manner as to feel the convexity of the cornea through the eyelid, when we shut the eye that is open, we shall feel that the cornea of the other eye is instantly elevated; and that it thus rises and falls in sympathy with the eye that is closed and opened. This change of the position of the eyeball takes place during the most rapid winking motions of the eyelids. When a dog was deprived of the power of closing the eyelids of one eye by the division of the nerve of the eyelids, the eye did not cease to turn up when he was threatened, and when he winked with the eyelids of the other side.*

* The experiment of cutting the facial respiratory nerve was performed on a dog. The following is the note made a few days after the nerve was cut:—The dog is now quite well, having suffered very little from the operation; when he fawns, the right side of his face is completely motionless; (the nerve of the right side

Nearly the same thing I observed in a girl whose eyelids were attached to the surrounding skin, owing to a burn; for the fore part of the eyeball being completely uncovered, when she would have winked, instead of the eyelids descending, the eyeballs were turned up, and the cornea was moistened by coming into contact with the mouths of the lacrymal ducts.

The purpose of this rapid insensible motion of the eyeball will be understood on

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was cut.) When I threatened to strike him, although there is a tremulous motion expressive of fear in all the muscles of the left side of the face, the other is perfectly still; he cannot even close the eyelid, and instead of winking when he expects to be struck, the eyeball itself is turned up. When he is excited, there is an expression of alacrity in all the muscles of the left side of the face, and a brilliancy in the left eye, while the right is perfectly inanimate. This is shewn in an extraordinary degree when he is fighting with another dog.

observing the form of the eyelids and the place of the lacrymal gland. The margins of the eyelids are flat, and when they meet, they touch only at their outer edges, so that when closed there is a gutter left between them and the cornea. If the eyeballs were to remain without motion, the margins of the eyelids would meet in such a manner on the surface of the cornea, that a certain portion would be left untouched, and the eye would have no power of clearing off what obscured the vision, at that principal part of the lucid cornea which is in the very axis of the eye; and if the tears flowed they would be left accumulated on the centre of the cornea, and winking, instead of clearing the eye, would suffuse it. To avoid these effects, and to sweep and clear the surface of the cornea, at the same time that the eyelids are closed, the eyeball revolves, and the cornea is rapidly elevated under the eyelid.

Another effect of this motion of the eyeball is to procure the discharge from the lacrymal ducts; for by the simultaneous ascent of the cornea, and the descent of the upper eyelid, the membrane on which the ducts open is stretched, and the effect is like the elongation of the nipple, facilitating the discharge of tears.

By the double motion, the descent of the eyelid and the ascent of the cornea at the same time, the rapidity with which the eye escapes from injury is encreased. Even creatures which have imperfect eyelids, as fishes, by possessing this rapid revolving motion of the eye, avoid injury and clear off impurities.

I may observe in passing, that there is a provision for the preservation of the eye, in the manner in which the eyelids close, which has not been noticed; while the upper eyelid falls, the lower eyelid is moved towards the nose. This is a part of that curious provision for collecting offensive particles towards the inner corner of the eye. If the edges of the eyelids be marked with black spots, it will be seen that when the eyelids are opened and closed, the spot on the upper eyelid will descend and rise perpendicularly, while the spot on the lower eyelid will play horizontally like a shuttle.

To comprehend certain actions of the muscles of the eye, we must remember that the caruncle and membrane called *semilunaris*, seated in the inner corner of the eye, are for ridding the eye of extraneous matter, and are in fact, for the same purpose with that apparatus which is more perfect and appropriate in beasts and birds.

The course of our enquiry makes some observation of these parts necessary.

In quadrupeds there is a gland for secreting a glutinous and adhesive fluid, which is seated on that side of the orbit next the nose; it is quite distinct from the lacrymal gland; it is squeezed by an apparatus of muscles, and the fluid exudes upon the surface of the third eyelid. This third eyelid is a very peculiar part of the apparatus of preservation. It is a thin cartilage, the posterior part of which is attached to an elastic body. This body is lodged in a division or depression of the orbit on the side towards the nose. When the eye is excited, the eyeball is made to press on the elastic body, and force it out of its recess or socket; the consequence of which is the protrusion of the cartilaginous third eyelid, or *haw*, as it is termed in the horse. By this mechanism the third eyelid is made to sweep rapidly over the surface of the cornea, and by means of the glutinous fluid with which its surface is bedewed, it attaches and clears away offensive particles.

In birds, the eye is an exquisitely fine organ, and still more curiously, and as we might be tempted to say, artificially protected. The third eyelid is more perfect; it is membranous and broad, and is drawn over the surface of the eye by means of two muscles which are attached to the back part of the eyeball, and by a long round tendon, that makes a course of nearly three parts of the circumference of the ball. The lacrymal gland is small, and seated low, but the mucous gland is of great size, and seated in a cavity deep and large, and on the inside of the orbit. As the third eyelid is moved by an apparatus which cannot squeeze the mucous gland at the same time that the eyelid is moved, as in quadrupeds, the oblique muscles are particularly provided to draw the eyeball against the gland, and to force out the mucus on the surface of the third eyelid. It flows very copiously; and this is probably the reason of the smallness of the proper lacrymal gland which lies on the opposite side of the orbit.

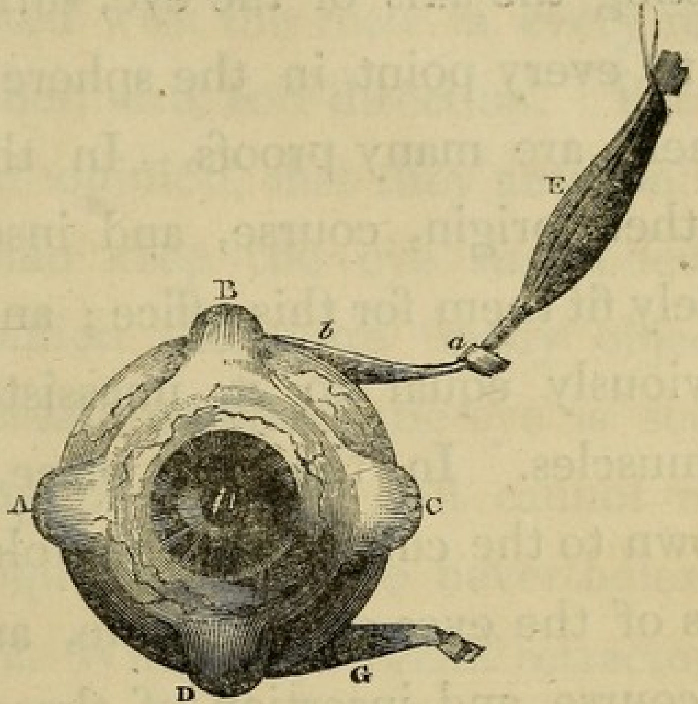
We already see two objects attained through the motion of these parts; the moistening the eye with the clear fluid of the lacrymal gland, and the extraction or rather the protrusion of offensive particles.

There is another division of this subject no less curious: the different conditions of the eye during the waking and sleeping state, remain to be considered. If we approach a person in disturbed sleep when the eyelids are a little apart, we shall not see the pupil nor the dark part of the eye, as we should were he awake, for the cornea is turned upwards under the upper eyelid. If a person be fainting, as insensibility comes over him the eyes cease to have speculation; that is, they want direction, and are vacant, and presently the white part of the eye is disclosed by the revolving of the eyeball upwards. So it is on the approach of death; for, although the eyelids be open, the pupils are in part hid, being turned up with a seeming agony, which however is the mark of encreasing insensibility.

It will now be admitted that the variety of motions to which the eye is subjected, require the complication of muscles which we find in the orbit; and it must be obvious to the most casual observer, that unless these various offices and different conditions of the eye be considered, it will be in vain to attempt an accurate classification of the muscles of the orbit.

Of the Actions of the Muscles of the Eye, and their natural Classification.

The muscles attached to the eyeball are in two classes, the recti and obliqui. The recti muscles are four in number, and come from the bottom of the orbit, and run a straight course forwards and outwards; they embrace the eyeball, and are inserted at four cardinal points into it. The obliqui are two muscles having a direction backwards and outwards *; they embrace



the eyeball, one passing over it obliquely, the other under it obliquely.†

* We may say so, for although the superior oblique muscle comes from the back of the orbit, yet, by passing through the trochlea, it has a course backwards and outwards to its insertion.

† *Expl. of the fig.* The muscles of the eye seen in front.

A. B. C. D. The recti muscles; voluntary muscles.

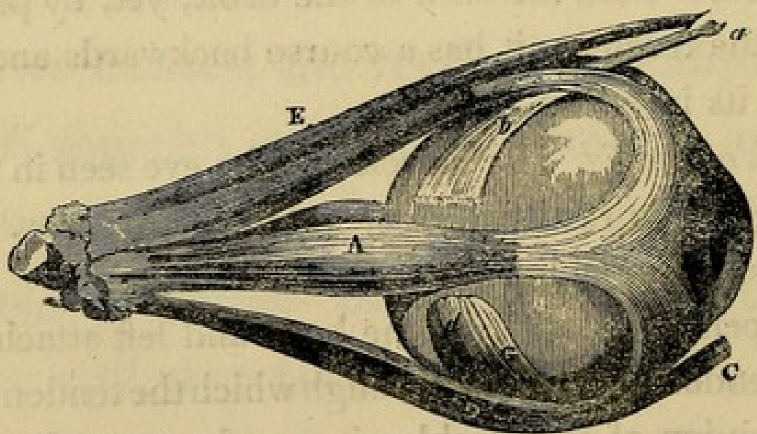
E. The superior oblique muscle or trochlearis.

a. The trochlea cut off from the bone and left attached to the tendon. It is a loop through which the tendon runs.

b. The tendon of the trochlearis muscle expanding and running to its insertion.

G. The inferior oblique muscle. It is seen, like the tendon of the superior oblique, to run backwards and outwards.

That the recti muscles perform the office of directing the axis of the eye, turning it round to every point in the sphere of vision, there are many proofs. In the first place, their origin, course, and insertion, accurately fit them for this office; and they are obviously equal to it, unassisted by other muscles. In the next place, from man down to the cuttle-fish, the voluntary motions of the eyes are the same, and the origin, course, and insertion of these muscles are similar, while the other muscles vary with the change of apparatus which is around the eye.*



* *Expl. of the fig.* The muscles of the eye seen in profile.

The oblique muscles of the eye stand contrasted with the recti in every respect, in number, size, and direction. Yet it is a received opinion, that they antagonize the recti, and keep the eye suspended. To this opinion there are many objections. 1. In creatures where the eye is socketed on a cup of cartilage and cannot retract, the oblique muscles are nevertheless present. 2. Where a powerful retractor muscle is bestowed in addition to the recti muscles, the oblique muscles have no addi-

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A. B. C. D. Three of the recti muscles. They arise together from the periosteum of the bottom of the orbit, and are inserted into the anterior part of the sclerotic coat of the eye.

E. The superior oblique muscle, or trochlearis.

a. The trochlea.

b. The reflected tendon inserted into the back and outer part of the sclerotic coat.

G. The inferior oblique muscle.

c. Its origin from the anterior part of the orbit.

d. Its insertion into the back and outer part of the eyeball.

tional magnitude given to them. 3. In matter of fact, the human eye cannot be retracted by the united action of the recti as we see quadrupeds draw in their eyes, which is an argument against these muscles being retractors, and therefore against the obliqui being their opponents, to draw it forward.

To these, other objections, no less strong, may be added. We have just found that certain very rapid motions are to be performed by the eyeball; now it can be demonstrated, that a body will be moved in less time by a muscle which is oblique to the line of motion, than if it lay in the line on which the body moves. If the oblique muscles were either opponents or coadjutors of the recti, there appears no reason why they should be oblique, but the contrary; for as the points of their insertion must move more rapidly than those of the recti, they are unsuitable. On the other hand, that there may be no difference in the time of the action and relaxation of the several classes, we see a reason why one rectus should be opposed by another, and why there being occasion for one oblique, its antagonist should also be oblique.

In proportion as a muscle gains velocity by its obliquity, it loses power; from the obliquity, therefore, of these muscles believed to be opposed to the recti, and from there being two of them to four of the latter, they are disproportioned in strength, and the disproportion proves that the two classes of muscles are not antagonists.

By dissection and experiment it can be proved, that the oblique muscles are antagonists to each other, and that they roll the eye in opposite directions, the superior oblique directing the pupil downwards and outwards, and the inferior oblique directing it upwards and inwards. But it is proved that any two of the recti muscles are equal to the direction of the pupil in the diagonal between them, and there is no reason why an additional muscle should be given, to direct the pupil upwards and inwards more than upwards and outwards, or downwards and inwards. It is evident, then, that the oblique muscles are not for assisting the recti in directing the eye to objects, but that they must have some other appropriate office. If we proceed farther, it must be by experiment.

Experimental Enquiry into the Action of these Muscles.

I. I divided the *superior rectus* or *attollens* in a rabbit, and felt something like disappointment on observing the eye remain stationary. Shortly afterwards, on looking to the animal while it was feeding, I saw the pupil depressed, and that the animal had no power of raising it.

The explanation I conceive to be this: during the experiment the eye was spasmodically fixed by the general action of the muscles, and particularly by the powerful retractor, a muscle peculiar to quadrupeds. But on the spasm relaxing, and when the eye was restored to the influence of the voluntary muscles, the recti, the voluntary power of raising the eye being lost by the division of the superior muscle, the eye was permanently depressed.

II. Wishing to ascertain if the oblique muscles contract to force the eyeball laterally towards the nose, I put a fine thread round the tendon of the superior oblique muscle of a rabbit, and appended a glass bead to it of a weight to draw out the tendon a little. On touching the eye with a feather, I had the pleasure of seeing the bead drawn up. And on repeating the experiment, the thread was forcibly drawn through my fingers.

By experiments made carefully in the dead body, (having distended the eyeball by dropping mercury into it to give it its full globular figure,) I had found that the action of the superior oblique muscle is to turn the pupil downwards and outwards, and that the inferior oblique just reverses this motion of the eye. In the above experiment there is abundance of proof that the superior oblique muscle acted, and yet the pupil was not turned downwards and outwards, therefore both oblique muscles must have been in action. Their combined action draws the eyeball towards the nose.

In the violent spasmodic affection of the eye, when it is painfully irritated, I believe that all the muscles, both of the eyeball and eyelids, are excited. In quadrupeds, I have ascertained that the oblique muscles act when the haw is protruded, but I have also found that the retractor oculi alone, is capable of forcing forwards the haw.

But quadrupeds having an additional apparatus of muscles to those of the human eye, are not suited for experiments intended to illustrate the motions of our eyes. The monkey has the same muscles of the eye with man.

III. I cut across the tendon of the superior oblique muscle of the right eye of a monkey. He was very little disturbed by this experiment, and turned round his eyes with his characteristic enquiring looks, as if nothing had happened to affect the eye.

IV. I divided the lower oblique muscle of the eye of a monkey. The eye was not, in any sensible manner, affected; the voluntary motions were perfect after the operation.

V. On holding open the eyes of the monkey, which had the superior oblique muscle of the right eye divided, and waving the hand before him, the right eye turned upwards and inwards, while the other eye had a scarcely perceptible motion in the same direction. When the right eye was thus turned up, he seemed to have a difficulty in bringing it down again.

From these experiments it is proved, that the division of the oblique muscles does not in any degree affect the voluntary motions by which the eye is directed to objects.

This cannot, however, be said of the involuntary winking motions of the eyes.

We have seen that in winking to avoid injury, the oblique muscles were in operation; and that the inferior oblique muscle gained in the power of elevating the eyeball by the division of the superior oblique, its opponent.

These revolving motions accompanying the winking motions of the eyelids, are of the utmost consequence to the preservation of the organ. A case which was some time under my observation proved this. By a defect of motion, the eye and eyelids remained fixed, and the consequence was that the cornea inflamed and became opaque. Another curious circumstance in this case was, that when the eyelids were closed, the patient still saw red light through the affected eye, the reason of which was that the eyeball did not turn up when the eyelid was closed.

If we close the eyes opposite to the window or before a candle, and continue to attend to the sensations of the eye, we shall still see red light coming through the eyelids. But if we make an effort to close the eyelids (though they be already shut), we shall be in momentary darkness, because during the effort the eyeballs are then turned up. Thus it appears that the dropping of the eyelid would make but an imperfect curtain before the eye, and the eye, to be entirely protected from the light, must have the pupil turned upwards.*

On the two Conditions of the Eye, its State of Rest, and of Activity.

The eye is subject to two conditions: a state of rest with entire oblivion of sens-

* In the case above alluded to, the patient had lost both motion and the common sensibility of the eye, the office of the fifth nerve was lost, yet the optic nerve retained its power, and he could see.

ation, and a state of watchfulness, during which both the optic nerve and the nerve of voluntary motion are in activity. When the eye is at rest, as in sleep, or even when the eyelids are shut, the sensation on the retina being then neglected, the voluntary muscles resign their office, and the involuntary muscles draw the pupil under the upper eyelid. This is the condition of the organ during perfect repose.

On the other hand, there is an inseparable connection between the exercise of the sense of vision and the exercise of the voluntary muscles of the eye. When an object is seen, we enjoy two senses; there is an impression upon the retina; but we receive also the idea of position or relation which it is not the office of the retina to give. It is by the consciousness of the degree of effort put upon the voluntary muscles, that we know the relative position of an object to ourselves. The relation existing between the office of the retina and of the voluntary muscles, may be illustrated in this manner.

Let the eyes be fixed upon an illuminated object until the retina be fatigued, and in some measure exhausted by the image, then closing the eyes, the figure of the object will continue present to them: and it is quite clear that nothing can change the place of this impression on the retina. But notwithstanding that the impression on the retina cannot be changed, the idea thence arising may. For by an exertion of the voluntary muscles of the eyeball, the body seen will appear to change its place, and it will, to our feeling, assume different positions according to the muscle which is exercised. If we raise the pupil, we shall see the body elevated, or if we depress the pupil, we shall see the body placed below us; and all this takes place while the eye-lids are shut, and when no new impression is conveyed to the retina. The state of the retina is here associated with a consciousness of muscular exertion; and it shows that vision in its extended sense is a compound operation, the idea of position of an object having relation to the activity of the muscles.

We may also show, by varying this experiment, that an agitated state of the muscles, or a state of action where the muscles are at variance or confused, affects the idea of the image. If we look on the luminous body so as to make this impression on the retina, and then cover the face so as to exclude the light, keeping the eye-lids open, and if we now squint, or distort the eyes, the image which was vividly impressed upon the retina instantly disappears as if it were wiped out. Does not this circumstance take place, because the condition of the muscles thus unnaturally produced, being incongruous with the exercise of the retina, disturbs its operation ?

If we move the eye by the voluntary muscles, while this impression continues on the retina, we shall have the notion of place or relation raised in the mind; but if the motion of the eye-ball be produced by any other cause, by the involuntary muscles, or by pressure from without, we shall have no corresponding change of sensation.

If we make the impression on the retina in the manner described, and shut the eyes, the image will not be elevated, although the pupils be actually raised, as it is their condition to be when the eyes are shut, because there is here no sense of voluntary exertion. If we sit at some distance from a lamp which has a cover of ground-glass, and fix the eye on the centre of it, and then shut the eye and contemplate the phantom in the eye; and if, while the image continues to be present of a fine blue colour, we press the eye aside with the finger, we shall not move that phantom or image, although the circle of light produced by the pressure of the finger against the eyeball moves with the motion of the finger.

May not this be accounted for in this manner: the motion produced in the eyeball not being performed by the appropriate organs, the voluntary muscles, it conveys no sensation of change to the sensorium, and is not associated with the impression on the retina, so as to affect the idea excited in the mind? It is owing to the same cause that, when looking on the lamp, by pressing one eye, we can make two images, and we can make the one move over the other. But, if we have received the impression on the retina so as to leave the phantom visible when the eyelids are shut, we cannot, by pressing one eye, produce any such effect. We cannot, by any degree of pressure, make that image appear to move, but the instant that the eye moves by its voluntary muscles, the image changes its place; that is, we produce the two sensations necessary to raise this idea in the mind; we have the sensation on the retina combined with the consciousness or sensation of muscular activity.

These experiments and this explanation of the effect of the associated action of the voluntary muscles of the eyeball, appear to me to remove an obscurity in which this subject has been left by the latest writers. In a most scientific account of the eye and of optics, lately published, it is said on this question, "We know nothing more than that the mind residing, as it were, in every point of the retina, refers the impression made upon it, at each point, to a direction coinciding with the last portion of the ray which conveys the impression." The same author says, "Kepler justly ascribed erect vision from an inverted image to an operation of the mind, by which it traces the rays back to the pupil, and thus refers the lower part of the image to the upper side of the eye." What can be here meant by the mind following back the ray through the humours of the eye? It might as well follow the ray out of the eye, and like the spider feel along the line. A much greater authority says, we puzzle ourselves without necessity. "We call that the lower end of an object which is next the ground." No one can doubt that the obscurity here, is because the author has not given himself room to illustrate the subject by his known ingenuity and profoundness. But it appears to me, that the utmost ingenuity will be at a loss to devise an explanation of that power by which the eye becomes acquainted with the position and relation of objects, if the sense of muscular activity be excluded, which accompanies the motion of the eyeball.

Let us consider how minute and delicate the sense of muscular motion is by which we balance the body, and by which we judge of the position of the limbs, whether during activity or rest. Let us consider how imperfect the sense of touch would be, and how little of what is actually known through the double office of muscles and nerves, would be attained by the nerve of touch alone, and we shall be prepared to give more importance to the recti muscles of the eye, in aid of the sense of vision: to the offices performed by the frame around the eyeball in aid of the instrument itself.

Of the Expression of the Eye, and of the Actions of the Oblique Muscles in Disease.

If, as I have alleged, the uses of the oblique muscles of the eye have been misunderstood, and if, as I hope presently to prove, the distinctions of the nerves have been neglected, the symptoms of disease, and the sources of expression in the eye, must remain to be explained.

During sleep, in oppression of the brain, in faintness, in debility after fever, in hydrocephalus, and on the approach of death, the pupils of the eyes are elevated. If we open the eyelids of a person during sleep or insensibility, the pupils will be found elevated. Whatever be the cause of this, it will be found that it is also the cause of the expression in sickness, and pain, and exhaustion, whether of body or mind: for then the eyelids are relaxed and fallen, and the pupils elevated so as to be half covered by the upper eyelid. This condition of the eye during its insensible unexercised state, we are required to explain.

It is a fact familiar to pathologists, that when debility arises from affection of the brain, the influence is greatest on those muscles which are, in their natural condition, most under the command of the will. We may perceive this in the progressive stages of debility in the drunkard, when successively the muscles of the tongue, the eyes, the face, the limbs, become unmanageable; and, under the same circumstances, the muscles which have a double office, as those of the chest, lose their voluntary motions, and retain their involuntary motions, the force of the arms is gone long before the action of breathing is affected.

If we transfer this principle, and apply it to the muscles of the eye, we shall have an easy solution of the phenomena above enumerated. The recti are voluntary muscles, and they suffer debility before the oblique muscles are touched by the same condition; and the oblique muscles prevailing, roll the eye.

If it be farther asked, why does the eye roll upwards and inwards? We have to recollect, that this is the natural condition of the eye, its position when the eyelids are shut and the light excluded, and the recti at rest and the obliqui balanced.

Although I am aware that medical histories do not often lead to the improvement of strict science, yet I am tempted to describe the condition of a patient now under my care, because it exhibits a succession of those phenomena which we seek to explain. He presented himself to me in the hospital, with a distinct squint, the left eye being distorted from the object. On the eyelid of the right eye there was a deep venereal ulcer; the man was in danger of losing the right eye, and required prompt assistance; but before he could be brought under the influence of mercury, the inflamed sore became deeper and the cornea opaque. The superior rectus muscle being, as I suppose, injured by the encreasing depth of the sore, the pupil became permanently depressed. The sight of the right eye being now lost, the left eye came into use; it was directed with precision to objects, he had no difficulty in using it, and it daily became stronger.

After a few weeks, medicine having had its influence, the sore on the upper eyelid of the right eye healed, the inflammation and opacity of the eye gradually diminished, the light became again visible to him; first it was yellow, and then a deep purple. And now the muscles resumed their influence, and the eye was restored to parallel motion with the other, and so as considerably to embarrass the vision. But the inflammation of the upper eyelid had been so great, as to diminish its mobility; and what appeared most extraordinary, the lower eyelid assumed the office of the upper one, and a very unusual degree of motion was remarked in it. It was depressed when he attempted to open the eye, and elevated and drawn towards the nose, when he closed the eye. But the upper eyelid was not only stiff, but diminished in breadth; so that notwithstanding the remarkable elevation of the lower eyelid, their margins could not be brought together, and we could perceive the motion of the eyeball; in his attempt to close the eye we constantly saw the pupil elevated, and the white part of the eye exposed.

I shall now attempt the explanation of these phenomena.

The impression upon the left eye had been weak from infancy, and the retina being unexercised, the recti, or voluntary muscles, wanted their excitement, and were deficient in activity; the involuntary muscles therefore prevailed, and the pupil was turned upwards and inwards, and consequently removed from the axis of the other eye. But when that other eye became obscured, the left eye being the only inlet to sensation, the attention became directed to the impression on the retina, the voluntary muscles were excited to activity, and they brought the eye to bear upon objects. This eye improved daily, because the natural exercise of a part is its stimulus to perfection, both in function and in growth. When the right eye became transparent, and the light was admitted, the voluntary muscles of that eye partook of their natural stimulus, and commenced that effort in search of the object, which in the course of a few days brought the eye to its proper axis, and both eyes to parallelism.

The next thing that attracts our attention in this short narrative, is the revolving of the eyeball. It has been explained in a former part of the paper, that when the eyelids are shut, the recti, or voluntary muscles, resign their office, and the inferior oblique muscle gains power, and the eye-ball traverses so as to raise the pupil. It will not have escaped observation, that the pupil of this eye was depressed, and could not be elevated by a voluntary act for the purpose of vision, owing, as we have supposed, to the injury of the rectus attollens, at the same time that it was thus raised involuntarily, in the attempt to shut the eye; a proof that this insensible motion is performed by the lower oblique muscle, and not the superior rectus muscle.

The circumstance of the lower eyelid assuming the functions of the upper one, and moving like the lower eyelid of a bird, reminds me of an omission in the account of authors. They have sought for a depressor of the inferior eyelid, which has no existence, and is quite unnecessary; for the motion of the *M. elevator palpebræ superioris* opens wide the eyelids, and depresses the lower eyelid, at the same time that it elevates the upper eyelid. If we put the finger on the lower eyelid when the eye is shut, and then open the eye, we shall feel that during this action the eyeball is pushed outwards; and we may observe, that the lower eyelid is so adapted as to slip off the convex surface of the ball, and is consequently depressed. The reason of this is, that the muscle which raises the upper eyelid passes over a considerable part of the upper and back part of the eyeball, and the origin and insertion of the muscle being under the highest convexity of the ball, that body must be pressed forwards in proportion to the resistance of the upper eyelid to rise. In the preceding case the upper eyelid being stiff and unyielding, both the origin and the insertion of the *elevator palpebræ* became fixed points; consequently, the action of the muscle fell entirely on the eyeball itself, whereby it was forced downwards and forwards in an unusual manner, and so depressed the lower eyelid to an unusual degree. Thus the muscle became a *depressor* of the inferior eyelid, instead of an *elevator* of the upper eyelid! The motion of elevation in the lower eyelid was of course performed by an encreased action of the lower portion of the *orbicularis palpebrarum*.

The Author has to regret that these minute circumstances regarding the action of muscles of the eye have led him to so great a length; he hopes they are not altogether without interest in themselves, while the discussion will afford him secure ground for establishing an arrangement of the nerves of the eye, and will enable him to distinguish them according to their uses.

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SECOND PART OF THE PAPER

ON

THE NERVES OF THE ORBIT.

From the Philosophical Transactions.

SECOND PART OF THE PAPER

ON

THE NERVES OF THE ORBIT.

[*Read before the Royal Society, June* 19. 1823.]

In these Papers I endeavour, to the utmost of my power, to distinguish between the facts which I am able to substantiate, and the hypothesis by which I have been directed in my inquiries. I hope that the importance of the facts may give some bias in favour of that mode of reasoning by which they have been discovered, and an additional interest to anatomical studies.

In my endeavour to arrange the nerves of the orbit, I encounter, in the first step, all the difficulties of my subject; for although there be only nine nerves properly enumerated as proceeding from the brain, six of these go to the eye; the second, third, fourth, part of the fifth, sixth, and seventh, go into the orbit, and may be said to be concentrated into a space no larger than a nut-shell.

In this investigation it is not always possible to give demonstrative evidence, or to answer opposition by cutting across a nerve; here we must proceed on a minute investigation of the anatomy, and by reasoning, rather than by experiment: yet I shall demonstrate what was stated hypothetically, in a former paper, that there is a correspondence between the compound functions of an organ, and the nerves transmitted to it.

Of the Function of the Ophthalmicus, a Division of the Fifth Nerve.

We are, in the first place, to enquire by what nerve the common endowment of sensibility is bestowed upon the membranes and surfaces of the eye. On recurring to this subject we are reminded, that the sensibilities of the body differ as much in kind as in degree; that the sensation of pain is provided to rouse our activity, and guard us against violence, or, by means more direct, to excite instinctive motions, which shall anticipate the most rapid actions of the will, and serve as a more perfect safeguard. The trigeminus, or fifth nerve, bestows upon all the surfaces of the head and face, external and internal, that sensibility which is enjoyed by the rest of the body through the spinal nerves. But through some of its branches is also bestowed that distinct sense on certain parts, for the purpose of drawing the muscles into combination; as, for example, that fine sensibility of the surface of the eye to the presence of minute particles, which at once excites the flow of tears, and draws the muscles into a combination to expel the offensive matter.

It has been shown in a preceding paper, by experiment, that on dividing the branch of the fifth nerve to the cheek and lips, the skin was deprived of sensibility, although in possession of other nerves, and enjoying muscular activity. The same has been proved in regard to this ophthalmic division; for if that branch of it which comes through the orbit and mounts upon the forehead, be divided, the skin will be deprived of sensibility, while the motion of the eyebrow will remain entire.

These facts are so strong, that when supported by the symptoms of disease they afford no apology for deep dissection in the living animal, and authorize the conclusion, that all the branches of the same division resemble each other in function, and bestow sensibility on the parts within, as well as on those without.

That the ophthalmic nerve may be deprived of its function, and the parts supplied by it of their sensibility, we may learn from the following instance, communicated to me by Mr. Crampton, of Dublin. To understand the inference from the following short narrative, it is only necessary to remember, that the nerve in question goes through the orbit, supplying the parts contained in it, but that it also extends its branches to the angle of the eye, eyelids, and forehead. "A few days after the discharge from the ear had ceased, the eye became entirely insensible to the touch. This loss of feeling extended to the lining of the eyelids, to the skin covering them, and to the skin of the cheek and forehead, for about an inch surrounding the eye: it did not go beyond the middle line of the face. When she told me her eye was *dead* (as she expressed it), to be certain, I drew my finger over its surface; and so far was this from giving her pain, that she assured me she could not feel that I was touching it at all. The eyelids made no effort to close while I was doing this, but the conjunctiva appeared sensible to the stimulus, as a number of vessels on the surface of the eye became immediately injected with blood."

Here we have an insensibility of the eye itself corresponding with the insensibility of the skin, which latter part we know possesses sensibility through the *fifth nerve;* and we therefore conclude, that it is the affection of the same nerve near its root, to which we have to attribute the insensibility of the surfaces of the eye, as well as of the skin round the eye. We must observe in this case, as in others of which I have had experience, vision, that is the function of the optic nerve, remained entire during the loss of common sensibility.

By experiment it can farther be made evident, that the sensibility of the eye, enjoyed through the ophthalmic nerve, does not bestow on the organ directly the power of combining the muscles, either for the defence of the eye, or for any other purpose. The impression must be referred back to the brain, and the muscles excited by their proper nerves. I have not been able to excite the motion of the eye by irritating the ophthalmic division of the fifth after the division of its root *; and in the instance just given, the eyelids did not move when the surface of the eye was irritated, because no sensation was conveyed inward to the sensorium, and consequently no mandate transmitted from it. The young lady could see, and could move the eye and eyelids; the eye itself was irritated by touch, as appeared from the rising inflammation; but by the insensibility of the ophthalmic nerve, a link was lost in the relation necessary to join the action

* In attempting to excite the muscles of the eye by galvanism sent through the fifth nerve, the muscles of the jaw were affected.

of the muscles to the sensibility of the surface.*

Of the Nerves performing the involuntary Motions.

We have just seen that nerves in great profusion come out upon the eyelids and forehead, and until these experiments were made, it was supposed that they directed the motions of the forehead and eyelids. But I have found that they have nothing to do with this function. On the contrary, a very small branch of the respiratory nerve of the face, that nerve which comes out before the ear, controls the motions of the forehead and eyelids. If this small nerve be divided, then the motions of the eyelids are lost, and they remain open. If, on the

* See the case below of Martha Symmonds.

contrary, all the nerves, that is to say, the second, third, fourth, and fifth, should be destroyed, and this small twig remain entire, the *contractions* of the eyelids remain perfect. The inquiries instituted in the first part of this paper give a lively idea of the consequences of the imperfection arising from the defect of this small branch of the respiratory nerve; showing that the eye, being unguarded and unwashed, becomes dry by evaporation, and inflames, and the cornea becomes opaque. It is unnecessary to point out the importance of this fact to the operating surgeon.

It has been asked, why should this nerve be called respiratory; and what have the actions of respiration to do with the eyelids? The name was given to excite attention to certain relations; that the question might be asked, and the connections of remote parts noticed and remembered. These connections of remote parts are so curious, the knowledge of them is sometimes so useful, and they are so immediately related to the present subject, that I may be permitted to explain them.

During the state of excitement of the respiratory organs, a very extensive consent of the muscular frame is necessary to bind together and support the textures, that they may bear the strain, either during violent efforts of the body, as in coughing, sneezing, &c. We may take the act of sneezing as a familiar example of the manner in which the eye is guarded during a sudden and violent act of expiration.

At the instant of this convulsive action of the respiratory muscles, a violent impulse is communicated to the head along the column of blood in the vessels of the head and neck. Every body is sensible of the eye flashing light at this moment; but the cause is mistaken, for it is supposed to be the impulse of blood forced into the eye; whereas it is the contraction of the eyelids to counteract the force of the impulse, and to guard the delicate texture of the eye. If the eyelids be held open during the act of sneezing, no sensation of light will be experienced, because the contraction of the eyelids upon the eyeball is prevented.

Can we believe this action of the muscle of the eyelids in combination with the action of the respiratory muscles, to be an accidental connection? Is it not rather a provision to compress and support the vascular system of the eye, and to guard it against the violent rush of blood which attends certain acts of respiration? If we open the eyelids of a child to examine the eye while it is crying, and struggling with passion, by taking off the natural support from the eye, the blood at the same time being forced violently into the head by the act of respiration, we shall see the conjunctiva suddenly fill with blood, and the eyelid everted.

The respiratory nerve of the face performs two offices, one of which is voluntary, as in moving the cheeks and lips in speech; and the other involuntary, as in moving the nostrils in breathing during sleep or insensibility. In like manner that branch of the respiratory nerve which is prolonged to the eyelids performs a double office, contracting the eyelids by volition, and also producing those involuntary winking motions of the eyelids which disperse the tears, and preserve the lucid surface clear, whilst it causes a correspondence in the motions of the eyelids with the act of respiration.*

But it has been observed, in the First Part of this Paper, that the shutting of the eyelids is not the only part of the act of preservation, and that the motions of the eyelids are attended with a rolling of the eyeball. How is this relation between the eyelids and eyeball established? This leads to an examination of the fourth nerve.

* Having distinguished the functions of the fifth and seventh nerves, a question still remains, whether the different operations performed by any one of them depend on the exercise of distinct filaments? I believe these filaments to be distinct nerves bound up together, and analogy would lead me to suppose them capable of distinct functions; but I cannot demonstrate this unless in the spinal nerves, where the roots are separate.

The Fourth Nerve.

This is a fine nerve, which takes its origin from the brain, at a part remote from all the other nerves which run into the orbit. It threads the intricacies of the other nerves without touching them, and is entirely given to one muscle, the superior oblique. We may observe, too, that this singularity prevails in all animals. What office can this nerve have in reference to this one muscle? Why is its root, or source, different from the other nerves,—from the nerve of vision, the nerve of common sensibility, and the nerve of voluntary motion? We now reflect, with increased interest, on the offices of the oblique muscles of the eye, observing that they perform an insensible rolling of the eyeball, and hold it in a state of suspension between them. We have seen that the effect of dividing the superior oblique was to cause the eye to roll more forcibly upwards ; and if we suppose that the influence of the fourth nerve is, on certain occasions, to cause a relaxation of the muscle to which it goes, the eyeball must be then rolled upwards.*

* The nerves have been considered so generally as instruments for stimulating the muscles, without thought of their acting in the opposite capacity, that some additional illustration may be necessary here. Through the nerves is established the connection between the muscles, not only that connection by which muscles combine to one effort, but also that relation between the classes of muscles by which the one relaxes while the other contracts. I appended a weight to a tendon of an extensor muscle, which gently stretched it and drew out the muscle ; and I found that the contraction of the opponent flexor was attended with a descent of the weight, which indicated the relaxation of the extensor. To establish this connection between two classes of muscles, whether they be grouped near together, as in the limbs, or scattered widely as the muscles of respiration, there must be particular and appropriate nerves to form this double bond, to cause them to conspire in relaxation as

The course of inquiry leads us, in the next place, to observe the vicinity of the root of this fourth nerve to the origin of the respiratory of the face, and we find them arising from the same track of fibrous substance. The column of medullary matter which constitutes that part of the medulla oblongata from which the respiratory nerves arise, terminates upwards, or at its anterior extremity, just under the corpora quadrigemina, and there the fourth arises. Is it possible, then, we say, that there can be any correspondence between the general act of respiration, and the rolling of the eye? Led thus to make the experiment, I was gratified to find it so easy to give the

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well as to combine in contraction. If such a relationship be established, through the distribution of nerves, between the muscles of the eyelids and the superior oblique muscle of the eyeball, the one will relax while the other contracts.

proof. On stopping the nostrils with the handkerchief, every effort to blow the nose will be attended by a rapid rising of the cornea under the upper eyelid. And on every occasion when the eyelids suffer contraction through the agency of the respiratory nerve of the face, as in sneezing, the eyeball is rolled upwards, undoubtedly through the agency of the fourth nerve.

I might, perhaps, be satisfied with having made the observation of these two facts; first, that there is such a combination of the motions of the eyeball and eyelids as I have before noticed; and secondly, that the nerves which move the eyelids, and the nerve of the obliquus muscle of the eyeball, are associated at their roots; but I should not do full justice to this interesting subject if I did not attempt something farther.

It is plain that we must consider the nerves and muscles of the eyelids in a double capacity, in their voluntary and involuntary actions. In the first, the motions of the eyelids combine with the whole muscles of the eyeball, as we may perceive in the voluntary contractions and squeezing of the eye; but in the insensible and involuntary motions of the eyelids, there would be no sympathy with the muscles of the eyeball, and therefore no correspondence in the motion of these parts, without a nerve of the nature of the fourth; that is, a nerve which having diverged from the root of the respiratory nerves, takes its course to the oblique muscles. In one word, the connection of its root declares the office of this nerve.

The expression of the eye in passion confirms the truth of this relation being established by a respiratory nerve, and consequently by a nerve of expression. In bodily pain, in agony of mind, and in all this class of passions, the eyes are raised and dragged, in conjunction with the changes to which the other features are subjected. If it be asked now, as it has been asked for some hundred years past, why the fourth nerve goes into the orbit, where there are so many nerves, why it is so distant in its origin from the other nerves, and why it sends off no twig or branch, but goes entirely to one muscle of the eye? the answer is, to provide for the insensible and instinctive rolling of the eyeball; and to associate this motion of the eyeball with the winking motions of the eyelids; to establish a relation between the eye and the extended respiratory system: all tending to the security or preservation of the organ itself.

Of the Voluntary Nerves.

The voluntary nerves of the eye are the third and sixth. The third nerve arises from the crus cerebri; that track of medullary matter which gives off all the nerves purely of volition. It is given to the muscles of the eye generally, and to no part but muscles. For these reasons we retain the name *motor oculi*, given by Willis, although his reasons for calling it so were fanciful and unsatisfactory. The fifth nerve, by its ophthalmic division, gives branches to the muscles of the eye, but not so profusely as to the surrounding parts; and not more than sufficient to give them sensibility in the degree possessed by muscular substance generally. Since the branches of this fifth nerve, transmitted to the muscles of the eyelids and forehead, do not minister in any degree to muscular action there, it would be unwarrantable to suppose that they served the purpose of giving action to the muscles within the orbit. For these reasons, I conceive the third nerve to be that which gives volition to the muscles of the eye, and that it is, of all the nerves of the body, the most perfectly and directly under the power of the will.

The *sixth nerve* is called *abducens*, and *motor externus*. With regard to its origin and distribution, there is no obscurity in this nerve; it arises from the same track of medullary matter which gives rise to the motor nerves, and it is distributed to a voluntary muscle, the *rectus externus*. In this respect it is like a subdivision of the third, and without doubt it is a voluntary nerve; but there is a circumstance in its connection which I cannot explain. It receives a gross branch from the great visceral nerve called Sympathetic. This nerve, ascending through the base of the skull, unites with the sixth nerve as it is entering the orbit. Some, having proceeded so far, would be inclined to call this an accidental connection, and so leave it; but similar investigations for many years have brought me to the conviction that there is no accident in an animal body; and comparative anatomy proves this to be a regular established relation.

To return to the consideration of these nerves of volition as they regard the eye, we may affirm, that although they want sensibility, in the common acceptation of the term, they no doubt furnish the mind with the rudiments of certain sensations, and so far resemble the nerves of the senses. From experiments narrated in the first part of this paper, it appears that we are sensible to the degree of agency exercised by the voluntary muscles of the eye. These nerves, the third and sixth, although they receive no external impression, are nevertheless agents which give rise to the perceptions of place or relation, in aid of that sensibility enjoyed by the optic nerve and retina.

I shall conclude these observations with a case which will now serve the reader as an anatomical exercise:—

Martha Symmonds, ætat. 41, Northumberland Ward.—This woman was admitted into the hospital for a disease apparently seated in the left orbit. Nine months ago she had a paralytic stroke, attended with the loss of power in her right arm, and she lost the sensation of the arm, neck, and face, on the same side. She lost, also, her power of speech, excepting only to "babble," as she says. She recovered from this attack, and went into service. About eight or ten weeks ago she was alarmed by a commencing dimness in both her eyes, and she was obliged to leave her place on account of this dimness of her sight. Both her eyes were equally affected, and there was no redness or opacity perceptible in either of them. She placed herself under a medical gentleman because she dreaded a return of the palsy. About six weeks ago the upper eyelid of the left eye fell, and she could not raise it. At that time she suffered great pain above the left eye, and the pain extended upon the left side of her forehead. She at the same time lost the vision of this eye, although she could distinguish by it the light of day from darkness. She could direct the motions of this eyeball as well as of the other at that time, and the appearance of the eye was natural.

Five days before she was admitted into the hospital, she experienced a violent deep throbbing pain in her left eye, and from that time the eyeball, as she says, became enlarged, until it projected considerably beyond the orbit. Two days before her admittance she was totally blind in that eye, and was deprived of sensation on the surface of the whole eye, eyelids, the internal corner of the nose, and upon the left side of her forehead.

At present her left eye is covered with its upper eyelid, and projects greatly from its natural situation. The lower eyelid is everted, as a consequence of the projection of the ball of the eye, and the conjunctiva is tumid and projecting. She cannot raise the upper eyelid, although, when it is raised with her finger, she can squeeze it down again, and winks with a motion which corresponds naturally with that of the other eye. It may be a question, whether the globe of the eye is enlarged or only protruded. The pupil is unnaturally large, and the iris is without motion. She cannot move the eyeball in any direction. The whole eye is insensible: she has just had her lower eyelid scarified, and she was not sensible of pain. She allows us also to press with our finger on the surface of the eye without complaining of any pain, or winking; although, as we said above, she can still wink, and does wink with this eyelid when the other eye is threatened.

Oct. 6. — To-day some further examination was made of this woman's face and head in order to ascertain the extent of insensibility. It was stated in our last report that she has lost sensation in the surface of the left eye and eyelids, in the corner of her nose, and upon the forehead. In these parts, she says that now the loss of sensation is less complete, because, when she had her eyelid scarified the other day, she felt pain, which she did not when it was scarified before. The eye also seems diminished in size.

Besides those parts which we have already described as being affected, she has, in a partial degree, lost sensibility to touch in that part of her cheek which is just under the orbit, and downwards upon the side of her nose, and upon the left side of her upper lip, and also within the cavity of the nose on the left side. However, when the point of the pin was brought near to the ear, or upon the skin which is over the lower jaw, she then was sensible of pain. A piece of linen was twisted so that it might be introduced into the left nostril: she allowed us to push it upwards so far as we could, and during this operation she only observed, that she was sensible of its presence. Turning it about within her nostril did not make her sneeze. When we tried the same experiment on the other nostril, she was unable to bear the tickling produced by the loose threads of the cloth, before it was introduced into the nostril. Now she informed us that she is in the habit of taking snuff: and she is not only insensible to its usual agreeable effects, but unconscious of its presence in the left side of the nose. We next made her close her right nostril, and inhale strong spirit of ammonia; and then repeated the same experiment on the other nostril. There was a very obvious difference in the effects produced by the ammonia on the two sides of her nose. She told us she could smell the ammonia on both sides; but still she could not bear to hold the bottle containing the ammonia so long at the right nostril as we observed that she could at her left. When the bottle was placed under the right nostril, its pungency affected her almost immediately, so much that she could not bear it; on the other hand, she allowed it to remain for a considerable time under the left nostril, and even snuffed it up strongly before she was inclined to remove it. During these experiments we observed that the right eye became suffused with tears, the left eye, on the contrary, appeared to be dry in its surface.

In order to ascertain further to what degree her sense of smelling was affected, we tried the effect of some substances which possess odour without pungency. On applying oil of anise-seed to her left nostril, while the right one was shut, she inhaled it powerfully, but was sensible of no smell. Then a piece of assafœtida was tried, but still she had no kind of sensation, either pleasant or the reverse. She was sensible to these odours on her right nostril.

The state of her mouth was examined; with the point of a pencil we pressed against the upper gums, on the left side of her mouth, and the inside of her cheek, where it is reflected off the gums, and she appeared to have either very slight or no sensation at all. She volunteered to put a spoonful of mustard between her gums and her cheek; and she seemed very little incommoded by such an experiment. The sensibility of the other parts of her mouth was natural.

The circumstances of this case make it difficult to determine exactly, where the disease is seated, which thus produces the destruction of the optic nerve, the third and fourth nerve, the first and second divisions of the fifth nerve, and the sixth nerve. Among these nerves we might add the olfactory nerve; but it may be made a question whether the function of that nerve is directly or indirectly affected: the issue of the case will probably determine this matter. However, from the condition of the parts without the orbit, we observe, that the power of closing the eyelid, and of winking, is retained, when the power of raising the eyelid is gone, and the sensibility of the eyelids, and of the eye itself, is completely lost. It is the portio dura which is distributed to the orbicular muscle of the eyelid, and bestows the power of winking. We see likewise that she can inhale powerfully, and can perfectly move the muscles belonging to the nostril and upper lip of the left side, when at the same time the skin which covers these parts is insensible. Still that power belongs to the portio dura. This nerve, passing to the face by a circuitous way, and being therefore uninjured by pressure within the orbit, permits her to move the left nostril and the side of her mouth in a natural correspondence with the other side of her face, although both the first and second divisions of the fifth nerve are included in the disease, and are destroyed along with the first, second, third, fourth, and sixth nerves.—*From the unpublished Reports of the Middlesex Hospital.*

I hope I have now unravelled the intricacy of the nerves of the head, and have correctly assigned to each nerve its proper office. In our books of anatomy, the nerves are numbered according to the method of Willis, an arrangement which was made in ignorance of the distinct functions of the nerves, and merely in correspondence with the order of succession in which they appear on raising the brain.

The first nerve is provided with a sensibility to effluvia, and is properly called olfactory nerve.

The second is the optic nerve, and all impressions upon it excite only sensations of light.

The third nerve goes to the muscles of the eye solely, and is a voluntary nerve by which the eye is directed to objects.

The fourth nerve performs the insensible traversing motions of the eyeball. It combines the motions of the eyeball and eyelids, and connects the eye with the respiratory system.

The fifth is the universal nerve of sensation to the head and face, to the skin, to the surfaces of the eye, the cavities of the nose, the mouth and tongue. *

* In this view of the fifth nerve, I have not touched upon its resemblance to the spinal nerves. But if we had ascended from the consideration of the spinal nerves

The sixth nerve is a muscular and voluntary nerve of the eye.

The seventh is the auditory nerve, and the division of it, called *portio dura*, is the motor nerve of the face and eyelids, and the respiratory nerve, and that on which the expression of the face depends.

The eighth, and the accessory nerve, are respiratory nerves.

The ninth nerve is the motor of the tongue.

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to the nerves of the head, we should then have seen that the fifth was the spinal nerve of the head; that it had a ganglion at its root, a double origin, and from its power over the muscles of the jaws and mastication, that it was a double nerve in function, being that nerve which bestows sensibility, at the same time that it sends branches to the original muscles; that is to say, to that class of muscles which are common to animals in every gradation. In all these respects it resembles the spinal nerves.

The tenth is the first of the spinal nerves; it has a double root and a double office; it is both a muscular and a sensitive nerve. It supplies the integuments and front of the head, to which the branches of the fifth do not extend.

Had I taken the nerves of any other complex organ rather than of the eye, I should have had an easier task. If I had taken the nerves of the tongue, I should have been able to prove by experiment, and in a manner the most direct, that the three nerves belong to three distinct functions, and stand related to three different classes of parts. I could have shown that taste and sensibility belong to the office of the fifth nerve, voluntary motion to the ninth, and deglutition to the glosso-pharyngeal nerve of the tongue.

In concluding these papers, I hope I may be permitted to offer a few words in favour of anatomy, as better adapted for discovery than experiment. The question lies between observation and experiment, and it may be illustrated by astronomy and chemistry. In the first, the objects being beyond our influence, we make observations, not experiments; and the science at length attains a state of perfection which raises our estimate of the human intellect. In the latter, for the most part, the subjects lie out of the sphere of mutual influence; they must be brought together by artifice, and chemistry becomes a science of experiment. But anatomy is more allied to the former than to the latter science, inasmuch as things are obvious to the eyes. In the animal body the parts present distinct textures, and are laid in a natural and perfect order; it is necessary only to trace the tubes, or to observe the symmetrical order of the nervous cords, in order to discover their respective uses: the motions, whether of the solid or fluid parts, are so regular and uniform, that the whole offers a subject for observation and induction. Anatomy is already looked upon with prejudice by the thoughtless and ignorant: let not its professors unnecessarily incur the censures of the humane. Experiments have never been the means of discovery; and a survey of what has been attempted of late years in physiology, will prove that the opening of living animals has done more to perpetuate error, than to confirm the just views taken from the study of anatomy and natural motions.

In a foreign review of my former papers, the results have been considered as a farther proof in favour of experiments. They are, on the contrary, deductions from anatomy; and I have had recourse to experiments, not to form my own opinions, but to impress them upon others. It must be my apology, that my utmost efforts of persuasion were lost, while I urged my statement on the grounds of anatomy. I have made few experiments; they have been simple, and easily performed; and I hope are decisive.

If we turn to the opinions which have been entertained on the subject of the brain and nerves, we find one theory to have prevailed from the Greek authors to the time of Willis, and to have descended from him, with little alteration, to modern writers. The brain has been supposed to secrete and supply a nervous fluid, and the nerves to be the conduit pipes for its conveyance. In every age the brain has been considered a common sensorium, and all the nerves to be capable of conveying sensation, unless when they had ganglia. If ganglia intervened, then the nerves were said to be cut off from the brain; and those so distinguished were called vital nerves, neither serving the purpose of governing the muscles, nor of conveying sensation. With all this apparent simplicity of doctrine, there never has been presented such a crude heap of errors, in the history of any department of science.

These notions were obviously founded on the mistake, that the same nerve served different purposes, and that a fluid moved in the same tube outwards to stimulate the muscles, and inwards to convey sensation of external impressions. So inconsistent are those opinions with the structure of the frame, that the simplest dissection proves them false.

So far is it from being true that ganglia cut off sensation, that I have ascertained, and proved by experiment, that all the nerves, without a single exception, which bestow sensibility from the top of the head to the toe, have ganglia on their roots; and those which have no ganglia are not nerves of sensation, but are for the purpose of ordering the muscular frame.

The hypothesis, that the nervous fluid streams out from the great officina along the nerves, has had an unfortunate influence in directing the labours of the experimentalists. During the last age it kept the pupils of Haller engaged in inquiries regarding the influence of the nerves: *de nu-*

tritione imprimis nervosa: and *de nervorum in arterias imperio;* and the interest of this question has not subsided, but, on the contrary, has increased among us.

This notion of a fluid moving backwards and forwards in the tubes of the nerves, equally adapted to produce motion and sensation, has perpetuated the error, that the different nerves of sensation are appropriated to their offices by the texture of their extremities, "that there exists a certain relation between the softness of the nervous extremities, and the nature of the bodies which produce an impression on them." On the contrary, every nerve of sense is limited in its exercise, and can minister to certain perceptions only. Whatever may be the nature of the impulse communicated to a nerve, pressure, vibration, heat, electricity, the perception excited in the mind will have reference to the organ exercised, not to the impression made upon it. Fire will not give the sensation of heat to any nerve but that appropriated to the surface. However delicate the retina be, it does not feel like the skin. The point which pricks the skin being thrust against the retina, will cause a spark of fire or a flash of light. The tongue enjoys two senses, touch, and taste; but by selecting the extremity of a particular nerve, or what is the same thing, a particular papilla, we can exercise either the one or the other sense separately. If we press a needle against a nerve of touch, we shall feel the sharpness, and know the part of the tongue in contact with the point; but if we touch a nerve of taste, we shall have no perception of form or of place, we shall experience a metallic taste.

The innovations of the celebrated continental authority Bichat, did not bring us a step nearer the truth. When he at once threw off respect for his contemporaries, and for the authority of those who had preceded him, he equally disregarded the facts of anatomy. There may be merit in taking new views of a subject, but Bichat was continually holding a thing up by the wrong end, and presenting it in an aspect so singular, as to puzzle any one to say whether or not it was that with which he had been long familiar; accordingly, what had been termed the sympathetic system of nerves, he called the ganglionic system; although they are not more distinguishable by ganglia than the other nerves, upon which, indeed, the ganglia are remarkable for their size, number, and regularity. These ganglia must not be thrown out of the system altogether, merely because they are contained within the skull and vertebræ, which circumstance should rather mark their importance.

Bichat persuaded himself that his ganglionic system was isolated, and a thing by itself; when, on the contrary, the connections of this part of the nervous system are universal. The wide-spreading fifth pair, and the thirty spinal nerves, give large and conspicuous roots to this system. It exhibits a tissue extending universally.

It was a still more unfortunate mistake of this ingenious physiologist, to suppose the sympathetic nerve to be the same with that, which in the lower animals (the vermes) is seen coursing from one extremity of the body to the other. In the leech, or worm, those nerves produce union and concatenation of all the voluntary motions, and bestow sensibility as well as motion; yet he saw in the sympathetic system of the human body, only the development of the same system of nerves, although he was aware that in man the sympathetic nerve bestowed neither sensibility nor the power of motion.

BICHAT announced his system with a popular eloquence, which had a very remarkable influence over all Europe. Physiologists yielding to him, mistook the importance of the several parts of the nervous system; and even the multiplied experiments of LE GALLOIS failed to convince them of the nature of the spinal marrow.

The experiments of M. LE GALLOIS were of the rudest kind possible. The spinal marrow was cut across, or destroyed, by passing skewers into the spinal canal, and the effects were observed; as if the spinal marrow were a simple body. Whereas, by such destruction of its substance, the original ganglia, which form a series along the spine, must have been hurt; the track of nervous matter which gives rise to the nerves of sensation; that also which gives roots to the nerves of voluntary motion; and the lateral column connected with the offices of respiration, must all have been destroyed by such coarse experiments. It cannot surprise us that the results were obscure and contradictory.

But the most extravagant departure from all the legitimate modes of reasoning, although still under the colour of anatomical investigation, is the system of Dr. Gall. It is sufficient to say, that without comprehending the grand divisions of the nervous system, without a notion of the distinct properties of the individual nerves, or having made any distinction of the columns of the spinal marrow, without even having ascertained the difference of cerebrum and cerebellum, Gall proceeded to describe the brain as composed of many particular and independent organs, and to assign to each the residence of some special faculty.

When the popularity of these doctrines is considered, it may easily be conceived how difficult it has been, during their successive importations, to keep my pupils to the examples of our own great countrymen. Surely it is time that the schools of this kingdom should be distinguished from those of France. Let physiologists of that country borrow from us, and follow up our opinions by experiments *; but let us continue to build that structure which has

* See the experiments of M. Magendie on the distinctions in the roots of the spinal nerves.

been commenced in the labours of the Monros and Hunters. *

* While printing the last sheets of the present edition of these papers, I took up Mr. Hunter's work on the Animal Economy, to consult him on the distribution of the nerves to the nose. I was as much surprised with the following passage as if I had never before read it. This work of Mr. Hunter was my earliest acquisition as a medical student, and often perused with deep interest; I believe I might trace back the course of my reflections to it, although for twenty years it never occurred to me that I was indebted to Mr. Hunter. I have often hung over the plates of Monro, certain that there was an arrangement to be discovered which would explain the seeming confusion of the nervous system, but I was not so sensible of what I owed to Mr. Hunter. I am happy that I fell so opportunely on this passage, and inexpressibly gratified to find a support of some of my opinions in such authority : —

" The nerves being in themselves, perhaps, the most difficult parts of an animal body to dissect, becomes a reason why we are still unacquainted with many of their minuter ramifications: yet, if a knowledge of these, together with that of their origin, union, and re-union, is at all connected with their physiology, the more accurately they are investigated, the more perfectly will

The whole history of medical literature proves, that no solid or permanent advantage is to be gained, either to medical or

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the functions of the nerves be understood. I have no doubt, if their physiology was sufficiently known, but we should find the distribution and complication of nerves so immediately connected with their particular uses, as readily to explain many of those peculiarities for which it is now so difficult to account. What naturally leads to this opinion is, the origins and number of nerves being constantly the same; and particular nerves being invariably destined for particular parts. The fourth and sixth pair of nerves are remarkable instances of this; and we may reasonably conclude, that every part has its particular branch allotted to it; and that however complicated the distribution may be, the complication is always regular. There are some nerves which have a peculiarity in their course, as the recurrent and chorda tympani; and others which are appropriated to particular sensations, as those which go to four of the organs of sense, seeing, hearing, smelling, and tasting; and some parts of the body having peculiar sensations (as the stomach and penis), we may, without impropriety, include the fifth, or sense of feeling. This general uniformity, in course, connection, and distribution, will lead us to suppose that there may be some general science, by physiological experiments unconnected with anatomy. To disregard the anatomy of the nervous system,

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other purpose to be answered more than mere mechanical convenience. For many variations have been described in the dissections of nerves, which I believe to have arisen from the blunders of the anatomist, rather than from any irregularity in their number, mode of ramifying, course, distribution, or connection * with each other. We observe no such uniformity in vessels carrying fluids; but find particular purposes answered by varying their origin and distribution: the pulmonary artery answers a very different purpose in the circulation of the blood, from that of the aorta; yet both arise from the same source, the heart. The course of the arteries is such as will convey the blood most conveniently, and, therefore, not so necessary it should be uniform; it not being very material to a part by what channel the blood is conveyed; though, in particular

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* "Here it is to be understood I do not mean lateral connection; such as two branches uniting into one chord and then dividing; or a branch going to a part, either single or double, for still it is the same nerve; or whether a branch unites with another a little sooner or a little later, for still it is the same branch. Such effects may arise more from a variety in the shape of the bodies they belong to, than any variety in the nerves themselves."

or to take it in the gross; to make a new science *of life*, and, influenced by a false analogy, to call it a fluid; to attempt to direct it along a cord or a wire, is to transgress

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instances, certain purposes may be answered by a peculiarity in origin and distribution, as happens in the testicle of quadrupeds. This observation respecting arteries is likewise applicable to veins, and still more to the absorbent vessels, in which last regularity is even less essential than in the veins. Whoever, therefore, discovers a new artery, vein, or lymphatic, adds little to the stock of physiological knowledge; but he who discovers a new nerve, or furnishes a more accurate description of the distribution of those already known, affords us information in those points which are most likely to lead to an accurate knowledge of the nervous system: for if we consider how various are the origins of the nerves, although all arising from the brain, and how different the circumstances attending them, we must suppose a variety of uses to arise out of this peculiar structure. Indeed, if we reflect on the actions arising immediately from the will, and affections of the mind, we must see that the origin, connection, and distribution of the nerves must be exact, as there are parts whose actions immediately depend upon such circumstances."

all the rules of philosophical enquiry, and must be attended with the rapid decline of anatomical studies. They will be considered as imposing restraints on genius, or be rejected as useless; and with them pathology, and all that is most necessary to medical science will fall into disuse.

THE END.

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