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CERTAIN PHYSIOLOGICAL INFERENCES

WHICH MAY BE DRAWN FROM THE STUDY OF

THE NERVES OF THE EYEBALL.

BY

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MDCCCXLI.

IV. *On certain Physiological Inferences which may be drawn from the Study of the Nerves of the Eyeball.* *By* W. P. Alison, *M.D., Professor of the Theory of Medicine.*

(Read 7th December 1840.)

It has been justly observed that the great discovery of the appropriation of the different portions of the Nervous System to the exercise of different functions, would never have been clearly established, but for the fortunate circumstance that, in certain parts of the body, especially on the face, the nerves of sense and of voluntary motion are distinct throughout their whole course. And this consideration may instruct us that, when we have an organ supplied with a variety of nerves, known to be of perfectly different endowments, the study of the peculiarities of these nerves may give us an insight into the purpose or use of some of those pieces of structure in all parts of the Nervous System, in which we must still admit that we see much contrivance, without understanding its intention.

In the case of the Eyeball, it is generally allowed that we see, separated for us by Nature, almost every kind of nerve which the physiology of any part of the body includes; we have the nerve of the special sensation, and that of common sensation; we have the nerves which excite motion in obedience to the will, and those which excite motion over which the will has no control; we can point out the incident nerve and the efferent nerve, concerned in two distinct examples of the reflex function of the spinal cord; and we can specify the nerve by which the nutrition of the whole organ, and more than one secretion contained in it, are liable to be influenced and controlled. And when we attend to the peculiarities of these nerves, and to facts which have been observed in regard to their action, I think we have sufficient data for certain inferences applicable to other parts of the Nervous System, which have not yet been distinctly pointed out, and which are steps in the progress of that most difficult, but likewise most interesting department of Physiology, where our object is to detect the laws by which mental acts are connected with the physical changes of living beings; and where, accordingly, the intimations of our own consciousness must be admitted as part of the foundation of our inferences.

I. The first peculiarity in the nerves of the eyeball to which I wish to direct attention is this, that those supplying the muscles by which the eyeball is instinc-

tively or voluntarily moved are, if not wholly (as SCARPA and others have maintained), at least almost entirely devoid of any of those filaments which we now regard as the organs of common sensation; the straight and oblique muscles having their nerves from the 3d, 4th, and 6th, to the almost complete exclusion of the ophthalmic branch of the 5th.*

I think we cannot doubt that the reason of this peculiarity, by which the muscles of the eyeball are distinguished—perhaps from every other muscle in the body, viz. the absence of purely sensitive filaments in their composition—is that already assigned by VAN DEEN,† viz. that these muscles are intended to be regulated and guided in their contractions, not by sensations excited in their own substance, or in parts directly in contact with them, but by the sensations of the Retina; and I think farther, that to this peculiarity we are to ascribe, both the positive fact, that the movements of these muscles are naturally *consentient* in the two eyes, so as to preserve the parallelism of the optic axes; and likewise the negative fact, that we have hardly any power to insulate an act of the will on one of these muscles, so as to move the one eyeball in a different direction from the other; *i. e.* the left eye, for example, turns inwards when the right eye turns outwards, because both are habitually guided by the sensations of the retina, which are similarly affected by these movements of the two eyes; and we have little power of moving either eye independently of the other, because we have hardly any sensations, consequent on the movement of the one eye and not of the other, whereby to guide the efforts of the will for this purpose.‡ And this consideration suggests some important reflections on the *office of sensitive nerves and of sensations* in regard to all movements of voluntary muscles.

It appears to me, notwithstanding some difficulties recently raised, that the essential peculiarity of all strictly Animal motion is, that it is motion dependent

* "Certum et inconcussum ut," says SCARPA, "quinti nervorum cerebri ramum ophthalmicum, orbitam transgradientem, ne minimum quidem filamentum valde conspicuis cæteroquin nervis oculum moventibus addere." (De Gangliis, &c. Isis, 1832.)

† De Differentia et Nexu inter Nervos vitæ animalis et vitæ organicæ, p. 162.

‡ It has been stated by Sir CHARLES BELL, that he believes the 3d nerve to be sensitive as well as motor, because it has an origin from behind as well as from before the grey matter of the crus cerebri; and although the examples of the portio dura and the spinal accessory nerves (which appear to be purely motor, although originating in part from the posterior portion of the cord) render that inference doubtful, yet I am bound to admit that, according to the statement of VALENTIN,* there is experimental evidence of sensations being felt on irritation of the 3d nerve. But this author is equally confident, from experiment, that there is no sensibility in the 6th nerve;† and it should be remembered that movements are often performed by the 3d nerve,—such as rolling the eyes inwards, and raising the eyelid,—which are not prompted by the sensations of the retinæ, and for the regulation of which sensations in the moving parts themselves may therefore be required.

* De Functionibus Nervorum Cerebralium, &c. p. 16. † Ibid. p. 30.

more or less directly on Sensation; that if we are certain of any movement in an organized body being altogether independent of sensation, and affording no indication of any mental act, we should refer it to the same class as movements in vegetables; and that in designating such movement as Organic, but not Animal, we express a distinction of essential importance in physiology.

It has indeed been lately maintained by several eminent physiologists, who have studied the indications of what is now called the Reflex Function of the Spinal Cord, that many living actions, such as respiration, deglutition, coughing, sneezing, and vomiting, the evacuation of the bowels and bladder, and even the movements by which irritations of the surface are avoided or repelled,—certainly attended in the natural state by sensations, and usually thought to indicate sensation, and therefore to belong to the department of animal life,—are independent of sensation, and ought, therefore, according to the principle above stated, to be referred to that of organic life. But although it is well ascertained that movements may be excited in perfectly paralytic limbs, by irritations applied to the surface, which must be carried back to the sensitive, and cross from thence to the motor portions of the spinal cord connected with those limbs; and therefore that the whole series of nervous actions which takes place when any of these reflex or sympathetic actions are excited, may be in some degree imitated by mechanical irritation of the nervous matter, independently of sensation; yet when it is inferred from this fact that, in *the entire and healthy body*, Sensation does not intervene, as a part of the sequence of cause and effect on which such actions depend, this theory overlooks so much of what has been formerly ascertained and pointed out in regard to them, that I do not think we can expect it long to hold its ground in physiology.

The movements which are excited by irritation of the sensitive nerves, in the *undoubted* absence of sensation (which of course can only be known in the human body in the state of disease), are general and irregular, and have not the character of *selection and adaptation* to particular purposes, which is essential to the useful application of any such actions in the living body. And when it is supposed that such movements as respiration, coughing, or deglutition, are equally independent of sensation, we not only overlook this, their essential character, of selection of individual nerves and adaptation to particular ends, but disregard the following facts, long ago stated in evidence, that sensations intervene in the process by which they are excited.

1. In various cases, impressions on the sensitive nerves of *different* parts of the body excite *the same* sensation, and then *the same* reflex or sympathetic action follows,—as when intense nausea results from changes whether in the brain, fauces, stomach, bowels, liver, or kidneys, and is in each case followed by the same act of retching,—or when a full inspiration follows the dashing of cold water on the face, breast, abdomen, or extremities.

2. Conversely, in various instances, different impressions made on *the same* parts of the body, and therefore on the same sensitive nerve, exert *different* sensations, in which case they are *not* followed by the same reflex actions. Thus certain impressions on the nostrils and face, followed by the sensation of cold or of tickling, excite the act of inspiration, but other impressions on the same parts, fully as strongly felt, but exciting different sensations, as in cutting or bruising, have no such effect; and the same is remarkably observed as to different impressions on the fauces and on the stomach, some of which excite nausea and *then* retching, while many others have no such effect. These facts plainly indicate that, in the natural state, the reflex actions, characterized as above stated, follow not the impressions on particular nerves, but the excitement of particular sensations. And it is easy to shew that many phenomena seen during sleep, or in decapitated animals (when the medulla oblongata has been left in connexion with the cord), and which have been thought indications even of well regulated reflex movements, independent of sensation, may be reconciled to the same doctrine, if we remember that sensations may be quite distinct, but momentary, and so leave no trace on the recollection.

Then it is to be remembered, that several of these reflex actions are absolutely identical with those which are excited by emotions and passions, *i. e.* by changes which are peculiar to the mental part of our constitution, as in the cases of sighing, weeping, laughing, even retching and vomiting; and again, that they are observed to be remarkably obedient to well known laws of mind. Thus they are, like the strictly voluntary actions, obedient to the law of habit, which, as applied to the mental changes preceding muscular contractions, is merely the law of association of ideas; and they are so effectually controlled by the occurrence of any very engrossing mental act,—sensation, emotion, or voluntary effort,—as plainly to imply, that they are not only attended by the consciousness, but modified by the agency, of the mental part of our constitution.

I stated and illustrated these facts, chiefly by commenting on the writings of Whytt and Monro, before the offices of the brain and the cerebellum, in animal motion, had been clearly distinguished from those of the spinal cord;* and it does not appear to me that their force is in the least impaired by the facts which have been since ascertained, touching the portions of the nervous matter with which sensation, or recollection, or any other mental act, is especially connected.

The case now before us, however, is one in which we see exemplified, not merely the power of sensations, directly, or through the intervention of other mental acts resulting from them, to *excite* muscular motion, but more especially their office in *guiding and regulating* those muscular actions which are excited through the nerves. The difference between the muscles of the eyeball and other

* See Edinburgh Medico-Chirurgical Trans. vol. ii.

muscles of the body in the respect above stated, illustrates perfectly the importance of the sensitive nerves of muscles, whether these are bound up with their motor nerves, as in most parts of the body, or separated from them, as in the face; and the importance of those muscular sensations, excited by the contraction of muscles, on the efficacy of which, as a means of acquiring knowledge, the late Dr BROWN dwelt with so much earnestness and ability, but perhaps with somewhat exaggerated ideas.

The office of the sensitive nerves of the voluntary muscles in general, and of the retina and the optic nerve in the eye, in regulating the animal motions, is obviously to furnish the sensations by which the mind is guided, in selecting the muscles and portions of muscles, and in determining the degree of contraction which is requisite for the attainment of any object. And of the necessity of such a regulator in the case of the eye, we have an instructive example when one eye is affected with anaurosis, the effect of which is to prevent that insensible eye from following accurately the movements of the sound eye, when turned in different directions, and thus to cause occasional and temporary distortion. In fixing on the muscles, or portions of muscles, on which it must act, when it feels certain sensations, in order to attain certain objects, the mind sometimes merely yields to that mysterious impulse, independent both of experience and of reasoning, to which we give the name of Instinct; but in the greater number of cases, in our species, it is guided by experience and education. The sensations which result from any particular muscular action are recollected; and it is the anticipation, or rather I believe we should say the *commencing recurrence*, of these sensations, which determines the repetition of the action. Thus the faculty of memory is essential to all strictly voluntary, as distinguished from instinctive, movements; and the experiments of FLOURENS and of HERTWIG instruct us, that it is the cerebellum, not the brain proper, which furnishes the physical conditions requisite for this recollection of muscular sensations.

Although there appears at first some difficulty in understanding how sensations which are only *anticipated*, or the *beginning* of which only is felt, can guide the contractions on which their perfect recurrence is to depend, we shall have no difficulty in conceiving this, if we recollect that it must necessarily be precisely in the same manner that a musician is enabled to go over any piece of music from recollection;—the anticipated sensation is throughout that operation the guide to the motion by which its own recurrence is to be secured.

In the performance of any such complex successions of muscular movements, we must allow that it is difficult to conceive, that there is not only a continual transmission *downwards*, perhaps to different parts of the body, of certain definite nervous actions resulting from efforts of the will,—by motor nerves,—but likewise at least as many transmissions *upwards* by the sensitive filaments, of changes

produced by the movements excited,—sensations thereby felt,—and mental determinations consequent on these, by which the successive volitions are guided. But it is admitted that, in all sciences, "Reason can sometimes go farther than Imagination can venture to follow;" and in no department of science can we more reasonably expect to meet with such examples than in tracing the actions of that exquisite mechanism, by which the sensations and powers of living animals are placed in connection with the world which is given them to inhabit.

But we may go a step farther, and understand more distinctly the mode in which sensations continually regulate and guide muscular actions, if we reflect on the phenomena to which MÜLLER has very properly directed the attention of physiologists under the name of *Consentient motions*, and of which the study of the eye furnishes us with some of the most instructive examples.

I need hardly say that this term is applied in cases where different nerves, and thereby muscles, are excited to action *simultaneously*, and where it is difficult or impossible to separate the combination. Such cases occur very frequently, both as to the strictly voluntary and the sympathetic or reflex movements, but especially as to the latter; and the following are the facts most important to be observed in regard to them.

1. The strictly voluntary motions thus simultaneously performed, are chiefly where the action that is willed requires considerable exertion, and is performed with difficulty. "Thus when we wish to contract the muscles of the external ear, we induce contraction of the occipito-frontalis muscle at the same time, without wishing it. During the most violent muscular action, many muscles act by association, although their action serves no apparent purpose. Thus a man making much exertion moves the muscles of his face, as if they aided him in lifting a load," &c.

2. In regard to most of the cerebral motor nerves, and nerves moving the trunk of the body, particularly when these act in obedience to sensation or emotion, the most important fact regarding their consentient action is, that this tendency is observed especially in *the opposite nerves of the same pairs*. Thus in the latter description of movements performed by the irides of the eyes, by the muscles of the face, by the pharynx, diaphragm, intercostal muscles, abdominal, lumbar, and perineal muscles,—in the actions of winking from bright light, of deglutition, breathing, coughing, sneezing, vomiting, laughing, sighing, weeping, —straining for evacuation of any of the viscera of the abdomen or pelvis,—it is certain, and is essential to the due performance of each action, that the corresponding portions of the nerves of the same pair, on each side of the body, should be affected, and should act on the muscles, exactly alike; and this is observed, even when the sensation exciting the movement is felt only through one nerve, and on one side of the body; as in the contraction of both pupils from bright light acting on one eye, or in the simultaneous and successive contractions of all

the muscles of respiration, in consequence of a sensation excited in one of the nostrils, or one of the bronchiæ.

3. Another fact as to these consentient movements, is satisfactorily observed *only in the eye*, but is no doubt extensively applicable in many parts, viz. that the stimulus of this consentient movement of voluntary muscles passes *through the ganglia*, and thereby affects muscles of strictly involuntary motion; the iris being distinctly observed to contract whenever the eyeball is voluntarily and forcibly rolled inwards by the action of the third nerve. And MÜLLER relates experiments in his own person, distinctly shewing that this effect takes place even on the pupil of the right eye, in consequence of forcible voluntary exertions made through the third nerve of the left eye, and when the right eyeball is not moved.

I think it impossible to doubt that MÜLLER is so far right in ascribing these phenomena to what he calls "the conducting power of the cerebral substance at the origin of the nervous fibres, whereby those which are contiguous to each other are liable to be affected simultaneously, and the influence of the will (or of any mental act) is with difficulty confined or insulated on individual fibres," or something is required to insulate it; and that these observations put us in possession of an important fact regarding the influence, either of volition or of sensation, or of the changes in the nervous matter attending these mental acts, in exciting muscular action, viz. that this influence naturally extends to some distance in the larger masses of the nervous matter, and requires the action of some additional cause, to *insulate* it on individual muscles, or portions of muscles. And in so far as the motor influence dependent on sensation is concerned, this is strictly in accordance with what is observed as to the imitation of that influence, in experiments on the reflex function in paralyzed or decapitated animals.

I think MÜLLER is also certainly right in supposing that the tendency to consentient movement in the similar or corresponding portions of any pair of nerves, is the reason why the third nerve is not employed to give the movement outward to the eyeball; two other nerves (the fourth and sixth) being employed to give this movement, because it is a movement which must always be consentient with that excited in a dissimilar part, and therefore through dissimilar nerves, on the other side of the body. And although this tendency to consentient motion is much less seen in the nerves of the same pair going to the extremities, yet MÜLLER justly observes, that the extreme difficulty always felt in rotating one arm in one direction, and the other in the opposite at the same moment, must be ascribed to the violation implied in that effort, of this tendency to consentient action in the corresponding portions of the same pairs of nerves.

But I think it also certain, particularly from what we see in the eye, that this observation goes but very little way in explaining the general phenomenon of Consentience. The tendency to consentient action in the nerves of the same pair in any part of the extremities, is so slight as to shew, that the conducting

power at the origins of these nerves cannot be very strong, and, therefore, that proximity of origin can afford but a very imperfect explanation of the very strong tendency to consentience remarked in almost all the motions of the trunk of the body. Consciousness informs us that, although it is very difficult to act at the same moment on dissimilar portions of the same pair of nerves, yet there is in general no difficulty in refraining from acting at the same moment on the corresponding portions; and in no case any difficulty in acting, at the same moment, on dissimilar and distant nerves. And there are facts observed in the eye, which have quite the value of the experimentum crucis, as shewing, that the chief cause of consentience of movement in our muscular organs is very different from the connection of nerves, at their roots or in their course. These facts are, that while those corresponding portions of the 3d nerve, which elevate and depress the eyeball, *i. e.* those which go to the superior and inferior recti, always act simultaneously; those which go the rectus internus and inferior oblique do not usually act together in the two eyes. Again, the 4th and 6th nerves never act together on the two sides of the body, but each is uniformly combined in its movement with a portion of the 3d on the other side. The reason obviously is, that the *Sensations* which result from the action of the 4th and 6th nerves of the one eye, cannot be identified with those which result from the action of the nerves of the same pair in the other eye, and cannot be separated from those which result from the action of that portion of the 3d pair in the other eye. There is no other circumstance, but the identity of the resulting and guiding sensation, which can be pointed out as existing where the consentience is observed, and not existing where it is not observed.

From these facts, therefore, we learn that the main cause of Consentience of muscular movement is simply *Identity of the Guiding Sensations.* Whether it is by an original instinct, or by repeated trials and acquired experience, that the acts of volition are directed to the nerves in each eye, which so turn the eyeballs as to keep the optic axes parallel, and so produce the single sensations, is a different question; but what has been stated seems to me quite enough to shew, that it is because the single sensations result, that these nerves are consentient.

I have no doubt that this principle, deduced from the movements of the eyeball, is strictly applicable to all the cases of consentient movement excited by the nerves of the same pairs on the face, fauces, thorax, abdomen, and pelvis, in the different actions which have been already mentioned. The movements which these nerves excite, are always followed by certain sensations, generally grateful, influenced by the degree in which the actions are performed; and by these sensations, the extent to which the actions are carried, and the energy with which they are performed, are felt to be habitually regulated. These resulting and guiding sensations are felt to be affected exactly alike by the movement which is

excited on both sides of the body; and hence we instinctively carry the movement to the same extent in both.

It was a speculation of DARWIN, that the actions of inspiration and expiration are originally determined by the uneasy sensation of anxiety in the chest of the new-born child leading to irregular and convulsive movements, out of which those are quickly *selected*, which are found by rapid experience to be effectual in appeasing that uneasy feeling; and although I do not agree to this statement, as expressing the order of events at that early period of life, and can assign no cause but Instinct for the original selection of the proper nerves and muscles for this purpose, yet I believe that, at all periods of life, it is the sensation felt to result from the action of inspiration already in progress, which determines the energy with which it shall be performed, the extent to which it shall go, and even the number of muscles that shall be excited to partake in it.

And that this is the true account of the matter, we have farther and satisfactory proof in the fact, that in various cases of disease, particularly in cases of Empyema, the contractions of the muscles of inspiration on one side of the chest become ineffectual for inflating the lungs, and for appeasing the sense of anxiety in the breast; in which case their nerves are no longer excited, and those muscles cease to act; they remain flaccid, and even, according to the observation of Dr STOKES, they gradually become paralytic from inaction; a phenomenon, as I conceive, almost exactly similar to the loss of power in some of the muscles of the eyeball in cases of amaurosis affecting one eye.

II. Again, another important application of the information acquired by study of the nerves of the eyeball, is to explain the use of the Plexuses or analogous contrivances, through which all the nerves, sensitive and motor, pass both to the upper and lower extremities, very generally in the animal kingdom.

In regard to the use of this very remarkable piece of structure, found in those nerves, by which the most forcible and the most nicely regulated muscular movements are effected, there have been various opinions. Several authors, among others Sir CHARLES BELL, have supposed it to be intended to facilitate the combinations of different muscles for particular actions, proceeding on the plausible supposition that, when the will acts simultaneously on several muscles, its influence proceeds from a single point, and is diffused from thence to those different muscles.

"The principal cause of the irregularity and seeming intricacy in the distribution of nerves, is the necessity of arranging and combining a great many muscles in the different offices. Wherever we trace nerves of motion, we find that before entering the muscles they interchange branches, and form an intricate leash of nerves, or what is called a plexus. This plexus is intricate in proportion to the number of muscles to be moved, 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. 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 by the extremity. 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 contractions of one class and the relaxation of another." In short, it appears to be his idea, that a plexus is necessary to enable a single effort of the mind to throw into action a combination of muscular contractions, and a succession of efforts to excite such a succession of these combinations as exists in every complex movement.

But the case of the muscles of the eyeball seems quite sufficient to set aside this opinion. None of these nerves on the opposite sides of the body are connected by plexuses, yet no nerves can combine their actions more perfectly or more surely. There is no more perfect consentience in the living body than that between the 6th nerve of the right eye, and the inner portion of the 3d of the left, and both are often exerted in varied combinations with many other nerves and muscles; but no nerves in the body can have less connection, so far as anatomy informs us, either at their origin or in their course.

In fact, when we reflect on what passes within us when we throw into action any two muscles at the same moment, we shall see that when such a voluntary effort is made, it is just as easy for us to excite simultaneously the most widely distant or the most closely contiguous muscles; and again, when we attend to the necessary *selection* of so many different and distant muscles, in any of the requisite combinations which are apparently under the influence of Sensation, as in coughing, sneezing, vomiting, &c. we shall perceive that, in the entire state of our faculties, any intense sensation may be said to have at its command all the muscles of the body; and although, as I have stated, I believe all mental acts to be guided by sensations in the selections which they make, yet I think it quite plain that neither proximity of origin, nor connection in their course, can be assigned as the cause of any of these selections.

I believe that Dr Monro made a nearer approach to the true statement of the use of a plexus, and put it in a simpler view, when he said, that "the chief intention of Nature in this very solicitous intermixture of the nervous fibrils, is to lessen the danger by which accidents or diseases affecting the trunks of the nerves would, without these contrivances, have been attended. Thus let us suppose, that two nerves are sufficient to supply the flexors and extensors of the forearm, it is evidently better for us that the one-half of each nerve should go to the flexors, and the other half of each to the extensors, than the whole of the first nerve should have gone to the flexors, and the whole of the second to the extensors. For if by accident

or disease one of these nerves should be cut across, or lose its powers, we should, on the first supposition, preserve one-half of the powers, both of flexion and extension, which would surely be preferable to our possessing fully the power of flexion without any power of extension. And thus, in the arm, where five trunks are found, there would on this supposition, as to the use of a plexus, be only one-fifth of the power lost, of performing any motion, by division of any one of these nerves."—(Obs. p. 45.)

That this is really the effect of this arrangement in regard to the effects of injury, appears to be sufficiently established by the experiments by PANIZZA on frogs, in which animals the plexus supplying the inferior extremities is much less intricate than in the mammalia. "If," he says, "one anterior root of the three last spinal muscles be cut, the motions of the corresponding extremity are as perfect as if the motiferous nervous system of the part had not been injured. Even if two roots be divided, although for a moment the motions are not so energetic as at first, yet they are speedily renewed, and the frog springs as if it had suffered no injury. Yet by this operation, more than two-thirds of the nervous matter which presides over the motion of the extremity is destroyed; and if the third filament is divided, all motion immediately ceases in the limb." "Whence, if I am not mistaken, appears the use of the nervous plexuses, which, by the intermixture of the filaments of different roots having a common function, establish among them, as it were, such a concentrated force, that each is adequate to preserve the integrity of the function, when, by means of any harm, the continuity of the other filaments is interrupted." (Edin. Med. and Surg. Journal, No. 126, p. 89.)

I am aware of experiments by CRONENBERG and by MÜLLER, who found that by cutting one of the nerves entering the crural plexus in the frog, they could paralyze or greatly enfeeble certain movements of a limb, and leave others unimpaired; and of the elaborate investigations of MÜLLER and others in Germany, which lead to this conclusion, that every nervous fibril, whether passing through a plexus or not, remains perfectly distinct from its origin to its termination. Notwithstanding these observations, it is distinctly admitted by MÜLLER, that "plexuses convey to each muscle of a limb fibres from different parts of the brain and spinal cord."

It seems to me, however, hardly possible to suppose, that this very carefully adjusted piece of structure is intended merely as a guard against injury, and therefore is of no use in any person or animal on whom such an injury as the section of one of the nerves of an extremity has never been inflicted. But if we advert to what has been said already of the evidence that any voluntary effort, which excites a muscle to contraction, extends its influence over *a considerable portion* of the cerebro-spinal axis, and at the same time to the evidence, in the experiments above quoted, that every muscle supplied from a plexus, has part of its motor nerves, and may be excited to contraction, from each of the nerves en-

tering that plexus, we can hardly miss the conclusion, that this contrivance not merely provides against injury, but *multiplies the power* which acts on each of these muscles, and enables the mind to *vary* the degree of energy which it can expend on each, in a degree much greater than in any case where it can act on a muscle only from a single point of the spinal cord.

Then, if we remember farther, that by means of the plexus, each *sensitive* nerve which supplies any muscle of the extremities, consists of fibrils coming from different points of the cord, we can easily perceive that, by this arrangement, the sensations resulting from each portion of the muscle may be more distinct, and more easily discriminated from each other, than those which are excited by nervous fibrils bound in the same sheath throughout their course, and originating beside each other in the cord.

Thus the effect and use of a plexus will be, to make the muscular sensations more precise and distinct, and to make the power which the will can exert over the muscles greater, and capable of greater increase at pleasure, than where such arrangement does not exist; and therefore, to increase the force and precision with which the efforts of volition may be directed and insulated on the muscles which are thus supplied with nerves. And I think that any one who attends to the subject may observe that he is actually conscious of these differences, when he compares the effects of his voluntary exertions in his extremities with the motions of his head and trunk.

I think, therefore, that Sir CHARLES BELL was right in asserting that the plexus enables the acts of the will to form combinations of muscular motions for definite ends, in greater variety and with greater precision than they otherwise could: but I apprehend the reason to be, not that each combination is effected by an impulse emanating from a single point, nor that the different combinations are *formed* in the plexus, but that the plexus, rendering the muscular sensations more distinct, and the acts of the will more energetic, enables the mind to act on all the muscles thus supplied with more power and precision, and to recollect and resume the action at any subsequent time with more certainty and uniformity, and thus facilitates combinations.

III. Let us next attend to the information given by the study of the nerves of the eye, as to the influence and use of the Ganglia of the Sympathetic nerve, of which it is generally admitted that the ciliary ganglion, furnishing the ciliary nerves, and through which the iris is moved, is a specimen and representative.

On this subject there has been much discussion at different times, which may be set aside as irrelevant or hypothetical, because proceeding on the supposition, that part of the office of the sympathetic, as of other nerves, is to *give* the vital power or energy to the muscles it supplies. It has always seemed to me extremely improbable, that any one of the solid textures of the living body should

have for its office to *give to any other*, the power of taking on any vital action; and that the only doctrine on this subject which involves no hypothesis, is that of HALLER, who regarded every part of the body which is endowed with irritability, as possessing that property in itself, but subject to excitement and to control, of one kind or another, from the nervous system; and the nervous system as exercising that control chiefly, and in the natural and healthy state probably only, in so far as it is the seat and the instrument of mental acts.

This doctrine, excluding the larger masses of the nervous system from all share in bestowing the property of irritability or vital energy on muscles, has received, as it seems to me, the only confirmation of which, in the present state of our knowledge, it stood in need, from the experiments of Dr REID, which were laid before the British Association in 1834, and have since been repeated on warm-blooded as well as cold-blooded animals. These experiments prove, that after the irritability of muscles has been, as nearly as possible, extinguished by irritation, it is perfectly recovered by rest, notwithstanding that all their connections with the brain and spinal cord have been cut.

There is, however, nothing hypothetical or visionary in the assertion as to the nerves, that "Soli in corpore, Mentis sunt ministri;" and, therefore, when we observe that all the great organs of involuntary motion, and among others the iris, have nerves which have passed through ganglia, and when we remember that all those organs are beyond the power of the *will*, but are peculiarly liable to control from certain *involuntary* acts of Mind, particularly from Sensations and Emotions, our business is to inquire whether there is any thing in the structure of those parts of the nervous system which can be supposed to unfit them for the one of those offices, and fit them for the other. And if we keep steadily in mind this precise object of our inquiries, we shall find the subject less obscure and intricate than it has often been thought.

When it is stated that the nerves which pass through the Ciliary Ganglion supply the only muscle in the eyeball, the actions of which are truly involuntary,—that all the truly involuntary muscles of the body have in like manner nerves which pass through ganglia,—and, farther, that all these ganglia appear, from the most recent and careful examination, to be, like the ciliary ganglion, formed of filaments both from motor and sensitive nerves, it is impossible to doubt, that much of what can be ascertained as to the office of this ganglion in the eye, must be truly applicable to the other ganglia supplying involuntary muscles in the body.

If we were to assert, however, that all nerves which excite involuntary movements in the body, in obedience to sensation or emotion, are ganglionic nerves, or that it is through ganglia only, that these involuntary acts of mind affect the body, we shall be immediately met by various examples of sensations (or the ner-

vous actions which attend sensations) certainly exciting movements through motor nerves destitute of ganglia. Of this, the portio dura and phrenic nerve furnish sufficient examples.

But setting aside the supposition that the ganglia are necessary to enable the involuntary affections of mind to act on the muscles, let us inquire how far the opinion long ago stated by Dr JOHNSTON and others is correct,—that the ganglia intercept the influence of the Will,—prevent the voluntary acts of mind from acting on the muscles which have their nerves only through them.

A decided opinion is given against this supposition, both by MÜLLER, and by his very intelligent translator Dr BALY. The reason given by MÜLLER is this, that as we know from the experiment formerly mentioned of forcibly acting on the muscles of the eyeball, and thereby causing contraction of the iris, that *a motor* influence can traverse the ciliary ganglion, there is no reason to suppose that *a voluntary motor* influence should be arrested in it, if really brought to it. He considers it, therefore, more probable, that the fibres of the "sympathetic, at their origin in the spinal cord and brain, are not in communication with the source of the voluntary influence;" *i. e.* that they are not set on the fibres by which the will acts downwards from the source of voluntary power; to which Dr BALY adds, that to suppose the admixture of other fibres in the sympathetic to have the effect of removing the motor cerebro-spinal nerves from the action of the will, is in opposition to one of the fundamental principles in physiology, that of the course and influence of nerves in their "peripheral part," *i. e.* at a distance from the brain and spinal cord, being *insulated*,—*i. e.* admitting of no admixture or transference of power from one filament to another. These authors, therefore, regard the ciliary nerves as beyond the influence of the will, by reason of the mode of their origin, not of their passing through the ciliary ganglion.

But, on the other hand, if we attend to the experiment insisted on by MÜLLER, we shall see that its result is not correctly stated by his expression, that it shews that a *motor* influence can be transmitted through a ganglion, and therefore gives us reason to presume that an effort of volition could traverse the ganglion also, if really carried to it. When the 3d nerve transmits an effort of volition to the muscles of the eyeball, and at the same time causes contraction of the pupil, it is plain that the influence which affects the iris has originated in the "source of *voluntary* influence" in the brain,—that it is not only a motor influence, but one consequent on a voluntary effort, which has traversed the ciliary ganglion. The ganglion has not prevented the influence of volition from acting on the nerves and muscular fibres which it supplies, although the will has no power of regulating the movement of these fibres; and this being so, I do not see how it can be denied that it has modified, in one way or other, the endowments of the nerves entering it; rendering them incapable, not of transmitting the influence of the volition, but of obeying any specific efforts of the will.

In fact, if it were in consequence of their roots having no connection with the motor portion of the brain and spinal cord, that the ganglionic nerves in the eye or elsewhere are not obedient to the will, and if the nerves underwent no change of endowment in the ganglia, we do not see why the motor nerves of the involuntary muscles (*e. g.* the motor filaments of the ciliary nerves) should pass through ganglia at all; they would be fitted for their function merely by their mode of origin.

Nor does it seem to me difficult to define a little more precisely the modes in which, in this as in other instances, by the connection established in every one of the ganglia of the sympathetic between motor filaments from the anterior, and sensitive filaments from the posterior, column of the spinal cord, the involuntary muscles, although we believe them to be supplied with motor nerves through the ganglia, are withdrawn from the power of the will.

1. Even if we implicitly rely on the experiments of VALENTIN and others in Germany, tending to correct the previous statements of HALLER, BICHAT, WILSON PHILIP, MAYO, and many others, and to shew that all the involuntary muscles may, under certain circumstances, be excited by physical irritations applied to their nerves,*—yet I think it cannot be doubted (from the negative result of so many experiments made previously by so many experienced physiologists) that the power of the motor nerves to excite muscular contraction is *greatly diminished* by passing through ganglia. The contractions, so excited in involuntary muscles in these experiments, have followed irritation *above* the ganglia, or even in the central masses, much more surely than in the nerves *below* the ganglia; and their force, and the certainty with which they can be produced, are certainly much inferior to those of the contractions excited by similar means through nerves not ganglionic, *i. e.* voluntary muscles.

2. The vital agency of the *sensitive* nerves passing through the ganglia seems also to be much modified; they certainly do not shew on irritation, when in the natural state, nearly as much sensibility as other nerves; and their grand peculiarity seems to be, that although supplying the muscular fibres, they are incapable of transmitting those muscular sensations by which, in the case of the voluntary muscles, we are continually informed of the contractions we excite. Although the study of the eye teaches us that the influence of volition can traverse a ganglion, yet in no one instance in the body is this influence *felt to be exerted* on muscles placed beyond ganglia. And when we reflect on what has been said of the importance of the resulting and guiding sensations, in *insulating and directing* the efforts of the will, we shall easily perceive that the want of any such sensations in the present case, is sufficient to explain the inefficiency of voluntary efforts over those muscles. These seem to be results of the degree of intermixture

* See Valentin De Functionibus Nervorum, &c, p. 62.

of the motor and sensitive filaments (with the interposition of grey matter), which takes place in the ganglia, instead of taking place at the extremities of the nervous filaments in the muscular fibres themselves.

It is very well worthy of notice that there is one action of the eye, in which the ciliary nerves are essentially concerned, and in which there is a distinct *resulting sensation* consequent on their action, and that in that action the ciliary nerves and the iris may be said to act in obedience to the will: I mean that still mysterious effort, whereby the eye increases its own refracting power, and so enables the rays from an object brought gradually nearer it, to form a distinct image on the retina and excite a distinct sensation in the mind; which effort is uniformly coincident with a gradual contraction of the pupil. Here an effort of volition is made in the direction of the eye, and the continued gratification of the sense, resulting from that effort, in so far as it affects the refractive power, seems to act the same part there, as the gratification of the sensations in the chest, in regulating the contractions of the muscles of respiration.

However, I am aware that objections may be stated to these speculations; and probably it is wiser to rest at present on the general inference, deducible from a comparison of the ganglionic nerves of the eye and of other parts, that when the sensitive and motor filaments which connect a muscle with the spinal cord, meet in a ganglion before reaching the cord, their endowments are so far modified that the sensations thence resulting are rendered less precise; that the efforts of the will cannot be insulated on such a muscle, and, therefore, although capable of being influenced by the will, it is truly involuntary.

But it is obviously part of the design of Nature, in the construction of the ganglionic nerves, not only that they should withdraw the muscles they supply from the dominion of the will, but likewise that they should facilitate and increase upon them the power of what I have elsewhere called Sensorial Influence, *i. e.* the influence attending or resulting from Sensations and Emotions of mind, which we know to originate or to be excited exclusively in the larger masses of the nervous system, and to act with peculiar power on muscles and other organs which have their nerves through the ganglia. Here also the study of the eye gives us important information.

The ordinary action of the iris, in obedience to the stimulus of light, is certainly effected by a reflex action, in which the optic nerve, the corpora quadrigemina, and the 3d nerve are concerned, and which has been fully illustrated by the experiments of Mayo, Flourens, Valentin, and others. That the peculiar sensation of light, excited by the impression on the corpora quadrigemina, not only attends the action but regulates its degree, is at least highly probable; although it is right to admit, that the action occurs occasionally in cases of amaurosis, where the patient expresses himself as conscious of no sensation; and I do not think that there is so good evidence of the necessary interposition of mental changes in this action, performed by an involuntary muscle, as in the cases where

selected and regulated contractions of voluntary muscles are excited by the reflex function of the cord, as, *e. g.* in the contraction of the orbicularis oculi and of this muscle only, effected through the 7th nerve, on the same sensation being felt.

As the 3d nerve appears to have roots in the posterior as well as anterior portion of the crus cerebri, it is certainly quite possible that those of its filaments which enter the lenticular ganglion are set on sensitive, not on motor portions of the cerebro-spinal axis; but if so, the observations already made shew that they are capable of being excited by an influence acting downwards from the strictly motor portions.

The indirect and probably modified influence, resulting from volition, and transmitted through the ganglia to the involuntary muscles, and of which we have this unequivocal example in the eye, is in itself in all probability an important part of the design of Nature in the construction of the sympathetic nerve and its ganglia. I perfectly agree with MÜLLER, that it is in this way only, that the effect of muscular exercise on the action of the heart, and much of the beneficial strengthening effect of exercise, is to be explained; and this indirect influence of voluntary muscular exertion on the heart is obviously important, as keeping its actions in unison with any occasionally required increase of voluntary muscular exertion; and so enabling us to keep up exertions which must otherwise have failed. And a slighter degree of the same indirect influence of exercise is seen in the movements of the stomach and intestines, which become to a certain degree torpid from inactivity of the voluntary muscles. For this slighter agency of voluntary exertion on the moving organs supplied by the splanchnic nerves, there is probably provision made, in these nerves passing through a greater number of ganglia, before they reach the moving fibres, than the nerves of the heart, and therefore having the indirect influence of the voluntary efforts transmitted through them in a less degree of intensity.

But it is very important, in reference to the use of the ganglionic nerves, to observe, that the movement of the iris is capable of being affected, not only through the 3d nerve, but likewise through the 5th nerve and the sympathetic, *i. e.* by all the filaments which form part of the composition of the ciliary ganglion. I shall not enter on the observations which have been made on the differences observed in different muscles in this respect; nor on the speculations of some German physiologists as to the mode of action, particularly of the sympathetic, on the iris; but only observe that the effect chiefly observed from the section of both these nerves on the iris, is a gradual and permanent contraction of the pupil. The influence of both these nerves on the iris is therefore strictly analogous to the kind of influence observed in experiments on animals, from injury of different parts of the nervous system, or the sympathetic nerve, on other involuntary muscles, consisting, as MÜLLER states, "either in enduring contractions, or in a long-continued modification of the ordinary rhythmic action of the organ;" a

change, *e. g.* in the number and rapidity of the beats of the heart, or of the peristaltic movements of the intestines; in short, as HALLER long ago expressed it, a change of the property of irritability itself, as resident in these muscular organs.

Now, when we apply these observations generally, to the living actions of those muscles which have their nerves from the sympathetic, I think we can be at no loss as to the use of great part, at least, of the structure of this part of the nervous system. These nerves place the organs which they supply in connexion with the whole extent of the cerebro-spinal axis; we know, from the observations now stated as to the iris, that an influence may be transmitted to these organs through any of the nerves entering any one of the ganglia; we know, from such experiments as those of LE GALLOIS and Dr WILSON PHILIP, as well as from the effects of injuries on the human body, that injuries acting on any large portions of the brain or spinal cord, affect the heart at least, if not other of these organs, nearly alike; we know that, in the natural state, all these organs are peculiarly under the control of what I have called *sensorial influence*, *i. e.* an influence resulting from those changes in the nervous system which attend intense sensations and emotions of mind; we know, from various facts, some of which I have elsewhere collected,* that this sensorial influence, although often originating from an impression made on a single point, extends itself rapidly in different directions through the nervous matter, and that it can cross from the sensitive portions of the nervous matter to the motor portions, probably at any part of the spinal cord. The effect of any arrangement which brings a particular muscle into communication with many points of the cord, must be still more decided in regard to this sensorial influence, than as to the influence of volition as affected by a plexus. The purpose of the multiplied origins of the spinal accessory nerve, which appears, from the experiments of VALENTIN and others, to transmit an influence to a greater number of nerves, connected with the cervical plexus, than had been formerly suspected, and therefore to be essentially concerned in many complex actions consequent on sensation and emotion, is thus easily understood. Some observations already published by Dr REID, shew more precisely that in the case of the heart, just as in the case of the iris, the sensorial influence, or one exactly similar to it, affecting the contractile power of the muscle, may be transmitted through different nerves entering the ganglia, and so passing to the muscles; for he found that a violent blow on the head influenced the actions of the heart much less, when the sympathetic and par vagum were cut in the neck, than when these nerves were entire, shewing that a part of that influence passes through these nerves; and on the other hand, he found that when an animal in which these nerves had been cut was under the impression of fear, its heart's actions were quickened nearly in the usual way; shewing that another part of that influence must pass through

* Outlines of Physiology, p. 398.

other nerves. It seems impossible to miss the conclusion, that the arrangements and the communications of those ganglionic nerves are designed and adapted, according to the laws of nervous action,—while they intercept the direct influence of the Will,—to multiply and concentrate, on all the organs they supply, that equally certain, equally important, and more varied and extended influence which results from Sensations and Emotions of mind. And I think it appears clearly, from what has been said, that these are objects which the arrangements of this part of the nervous system must necessarily be so disposed as to secure.

IV. The last question which I shall here consider as elucidated by what we observe in the eye, relates to the mode of transmission of that Sensorial influence, resulting, in the natural state, from mental sensations and emotions, which affects the organic functions of Nutrition and Secretion, and, in all probability, the vital properties and composition of the blood itself, in all parts of the body.

It has been long known that the lacrymal gland is supplied so completely by the fifth nerve, that it must be through a branch of this nerve, almost exclusively, that the passions of the mind, or the sensation of pain excited in other parts of the body, must produce their effects on the flow of tears; and the experiments of Magendie, in which inflammation and ulceration of the conjunctiva and cornea, and ultimate collapse of the eye, followed section of this nerve, and some cases presenting the same series of phenomena in the human body (of which I have myself seen two), have shewn that the nutrition of the whole eyeball, and especially the secretion of mucus on the conjunctiva, are under the control of this nerve. It is hardly necessary to say, that the common expression of this nerve "presiding over these functions," is vague and unsatisfactory; but that it is the nerve destined to affect these functions, in the way in which nature intends them to be affected by changes in the nervous system, is sufficiently obvious; and is another general principle derived from observations on the eye, and manifestly applicable to the nerves of common sensation all over the body. I have formerly stated a conjecture, which I still think the most probable explanation of the inflammation excited by disease or section of this nerve, viz. that the sensitive nerve, which Sir C. Bell has well denominated the "guard of the organ," having thus lost its power, the irritations which, in the natural state, are applied to the mucous membrane, and by an action there, attended with sensation, determine a sufficient flow of the natural protecting mucus, now lose their effect, and the membrane is reduced nearly to the condition of a serous membrane, and inflames (as all serous membranes do), merely from the contact of the air.

This influence of sensitive nerves and of sensations, and this consequence of the want of such influence, I take to be an important point in the physiology of other mucous membranes as well as this; but we are moreimmediately concern ed

with the question, in what manner the fifth nerve is qualified for transmitting downwards the effect which sensations, even in distant parts of the body, and emotions or passions of the mind, have on the circulation through the eye, and on all its secretions.

The instance of the lacrymal gland, and of the mamma, (which, according to the dissections of MÜLLER, has its nerves merely from the intercostals, to the exclusion of the sympathetic,) are enough to shew, that the most intense agency of mental emotion may take place through the nerves of common sensation.

I think Dr MARSHALL HALL has good reason for the opinion which he has stated, that as the nerves which supply most of the internal organs of secretion, and of organic life in general, are ganglionic, and as the circulation in the eye itself is liable to influence from section of the sympathetic nerve as well as of the 5th, it is probable that the Gasserian ganglion, and the ganglia on the sensitive roots of the spinal nerves generally, must be designed for the influence of these nerves on secretion and nutrition, not for their functions in regard to sensation; but it seems to me much more doubtful, whether MÜLLER is right in his conjecture, that the *grey matter* of the ganglia, and the grey fibres passing from them along the nerves, are the parts of the nervous system designed exclusively to affect the organic functions of secretion and nutrition. There are no experiments to shew any such peculiar power in the grey matter of the nervous system; and I can state one fact which shews unequivocally that if it is, as MÜLLER supposes, through the grey matter in the Gasserian ganglion, and of the branches of the sympathetic which communicate, beyond that ganglion, with the fifth nerve, that any emotions or sensations affect the secretions of the eye, that grey matter must itself be acted on by the substance of the fifth nerve behind the ganglion. For in one of the cases of palsy, affecting the fifth nerve on one side, which was long under observation in the clinical ward, it was quite obvious that neither emotions of mind, nor sensations excited in the sound nostril, or in other parts of the body, affected the eye of the palsied side, which, although inflamed, remained always dry when the other was suffused on such occasions. Now, in this case it was ultimately ascertained by dissection, that the diseased (and ultimately wasted) portion of the nerve was behind the Gasserian ganglion, between it and the origin on the crus cerebelli; from which it appears quite certain, that the influence of mental sensation and emotion must pass downwards through this portion of the nerve (which I believe hardly contains any grey fibres) on its way from the sensorium commune to the eyeball.

Whatever may be the use of the grey matter in the ganglia, or in other parts of the nervous system, I think we cannot doubt that there is here a grand exception to the principle which has been laid down by several authors, that the same nerve is never employed to convey impressions upwards to the sensorium and downwards to the extremities of the nerves. At least, if there be a set of nerves

destined solely to convey the influence of sensation and emotion downwards to the organs of organic life, these nerves are every where bound up in the same sheath with the nerves of common sensation, by which impressions are carried upwards to the brain.

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Thus the study of the nerves of the eyeball enables us, I think, to give a decided opinion as to the following points:—

1. That all strictly animal muscular movement is not only excited, directly or indirectly, by Sensations producing it, but is continually guided and regulated by sensations which succeed and result from it.

2. That it is the province of these resulting sensations, *commencing or anticipated*, to determine on individual muscles the influence of the Will; and where distinct animal movements are always consentient, it is because the sensations thus guiding them are the same.

3. That neither the connections of nerves at their roots (so far as anatomy has detected them), nor the Plexuses which they form in their course, can be assigned as the cause of consentience of their movements, or of any combinations of their actions; but that the plexuses of nerves, placing both the sentient and motor nerves of the muscles of the extremities in connection with a large surface of the spinal cord, seem to be designed and fitted to render the muscular sensations more distinct, and the acts of the will more energetic than they otherwise would have been, and thereby to give power, facility, and precision to the combinations and successions of muscular contractions in all movements of the limbs.

4. That the action in nervous matter which is excited by an act of the will, can traverse a Ganglion, but is never felt to be exercised, and therefore cannot be applied to any specific object, beyond it, apparently because of a modification of the endowments, both of sensitive and motor filaments of nerves, where they are subdivided and intermixed with the grey matter of a ganglion.

5. That the motor filaments of nerves which have passed through ganglia may be affected by changes in the sensitive as well as the motor filaments which enter the ganglia; and that in this way, probably, the influence of sensations and emotions of mind (which must be transmitted through the ganglia, because it affects especially muscles which have only ganglionic nerves) is conveyed from many parts of the spinal cord, and concentrated on the muscles of organic life.

6. That the influence of changes in the nervous system, and especially of such as accompany sensations and emotions of mind, on the capillary circulation, on the functions of nutrition and secretion, and on the properties of the blood, may be transmitted downwards by the nerves of common sensation, and that it is probably with a view to this influence that the ganglia are formed on the roots of those nerves.