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ON THE MUSCLES OF THE EYEBALL, AND THE NERVOUS INFLUENCES WHICH REGULATE THEIR ACTIONS.

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MOST of the voluntary actions of our bodies are performed by us with reference only to the end which we have in view, while we generally remain unmindful of the mechanism by means of which they are produced; and with respect to the involuntary motions, which are the most important of all, provision is made for their continuance day after day, quite independently of our will, or even of our consciousness. Each muscular fibre employed in the former set of movements is under the influence of, and guided by, common sensation, or what may be termed the muscular sense. This may be appreciated by, and may act in concert with, the will. Thus we are quite conscious of the amount of effort made in endeavouring to raise a weight, although we do not move it. This sense it is which gives us the knowledge of the exact amount of force required in different muscles, in order that they may concur in producing any movement of the body. If this sense is impaired, or ceases to act in conjunction with the will, the muscles act irregularly, imperfectly, or not at all. When, for instance, the nerve of sensation has been paralysed in the head of a horse, the lower lip will hang, and the animal will be unable to eat its food, because it does not *feel* the amount of *effort* required in the several muscles to produce a combined action. Or, again, when a person loses sensation in his lower extremities, although the power of motion is unimpaired, yet will he be unable to walk, because he has no means of knowing or of indicating to each muscle the exact share which it should take in balancing his body. This sense may, however, be supplied by another under certain circumstances. Thus, well-known cases have occurred, in which the power of sensation was lost in the hand or arm, and in which anything placed in the hand would drop, the muscles receiving no intimation of the amount of action required of them. But, in such instances, if the eye were kept fixed on the object, it could be retained perfectly well in the hand. Hence, the sense of sight supplies the deficiency of the muscular sense. This observation tends to illustrate the way in which the muscles of the eye are regulated in their actions. Unlike other muscles, they have not, or possess in a very imperfect degree, a muscular sense in conjunction with the will; and in this respect their physiological relations are in some degree analogous to those of the involuntary muscles of the body. When the eyes are closed, for instance, we should not know in which direction they looked, were it not that the eyelids occasionally feel the prominent cornea beneath them; or, again, we should in vain require a blind man to fix his eyes upon any given spot; and the evident cause that he cannot do so, is that the sense which governs the muscles of the eye is absent.

The peculiar use of the muscles of the eye in directing it and adapting it to vision, in fact, requires that their actions should be regulated, not by common sensation, but by the sense of sight; and it appears that under these circumstances we remain unconscious of the amount of effort required in any particular action. A local plan of governing the movements of the eye is adopted, which does not depend upon, or communicate with, the general sensorium.

If the finger be placed on the eyelid, so as to feel the convex cornea, we shall become aware of the sudden and rapid motions of the eyeball which are habitually taking place, although generally we have no intimation of them when the eye is closed. In every act of winking, the eye is thrown up to the roof of the orbit, which we should never have known from common sensation, had it not been discovered by other means. In these instances, again, it becomes apparent that the muscles of the eye are not regulated by common sensation; but as the eye is nevertheless guided with the greatest precision in every act of vision, we cannot but ascribe the power which controls their actions to the sense of sight: a point in physiology which has not hitherto been duly acknowledged.

It is probably owing to the absence of the muscular sense in this region, that the means employed for the adaptation of the eye to vision at different distances have so long been made the subject of dispute. Could we be conscious of the effort made in altering the focus of the eye, we should probably be at no loss to ascertain the means by which it is effected; but as the adjustment of the eye takes place under the government of its own nervous influence, and is produced by its own construction, we can only reason upon it, without being able to test our conclusions by our sensations.

The muscles attached to the eyeball are of two kinds, the recti and the obliqui. The *recti* muscles arise from the bottom of the orbit, and run in a straight course over the sides, the upper, and the under surface of the eye. The *obliqui*, in man, have a direction backward and outward as they pass to their insertion; but in many animals, whose eyes are situated laterally, they are nearer the front part of the eye at their insertion than elsewhere; so that although in all animals they have a transverse direction (one passing above, and the other below the globe), yet in some they pass from behind forwards, and in others from before backwards,[1] in reference to the eyeball.

[1] As the position of the eye varies in different animals, the terms anterior and posterior, internal and external, are used in reference to the eye, the cornea being considered the anterior part.

The *recti* perform the office of directing the axis of the eye, turning it to every point in the sphere of vision, and are, as we have seen, under the control of the sense of sight. It frequently happens that one retina is much more sensitive than the other; and under such circumstances, the more feeble impression may be habitually disregarded. The controlling power may then likewise be deficient, and the two eyes may not usually be directed to the same object. A person thus affected will in vain endeavour, by any effort of the will, to direct the wandering eye to any object, as long as the impression of that object remains distinct on the stronger eye, but does so immediately that the more vivid impression is lost. Some individuals become practically aware of the fact, and close the stronger eye in addressing a person situated on the opposite side.

It is necessary for distinct vision, that the impressions on the retina should remain a certain time. If this condition is not complied with, confused images are produced. It is therefore necessary, not only that the eye should be moved from object to object, but that it should be capable of being fixed upon any point upon which the mind is intent. This is equally true, whether the object seen be at rest or in motion, and whether the eye itself be stationary or not. The straight muscles obeying the visual sense are sufficient to direct the eye to any point in the sphere of vision, and to keep it fixed upon such point during the time that the retina is duly impressed; and when the object seen is in motion, the recti muscles are all that is required to make the eye follow it as long as it moves in straight lines. But should it revolve upon its axis, it is obvious that the straight muscles could produce no corresponding motion of the eye. Or, again, if the head is moved in any other but a straight line, the recti muscles have no power of keeping the eye fixed upon an object during the time. In motions of this kind, therefore, in which the relation of the eye to external objects is changed, or when the external object moves in a circle, an apparatus is required by means of which the eye may revolve upon its axis, and so remain fixed with regard to the object seen during the time required for the due impression of the retina. A provision is made for this object in the oblique muscles, which, from their position in different classes of animals, should rather have been denominated "transverse". These embrace the globe of the eye, rotating it on its axis. The action of these muscles cannot be better illustrated than in looking at a carriage wheel in motion. If the eye is allowed passively to rest on the wheel, a confused image is produced, and no part is distinctly seen. But as soon as the separate spokes are observed, the eye is thrown into a series of slight rotatory motions, during each one of which it follows the wheel a sufficient time to see it distinctly. After each such motion, the eye regains its former position, and is again ready to follow the wheel to the same extent as before. Or when we look at an object, and move the head from shoulder to shoulder, the eye is moved in the arc of a circle whose centre is the neck, and the image of the object would be in constant motion upon the retina, were there not a provision for rolling the eye as well as directing its axis. It was formerly supposed, indeed, that the motion of images upon the retina gave the idea of the motion of the objects which produced them. Thus, Keill, in his *Introduction to Natural Philosophy*, p. 79, says:

"Those objects will seem to be moved, whose images are moved upon the retina." More accurate observation, however, shows us, that unless the eye is fixed for a certain, although it may be a very short period, upon an object, there can be no distinct perception of it. The point of sensation, the axis of the eye, and the thing seen, must be maintained, not only in the same straight line, but in their respective relations with regard to position, for a certain time, before a distinct impression can be produced.

The object, as has been observed by Hunter, becomes the fixed point, the centre of motion commanding the direction of the axis of the eye, as the north demands the direction of the magnetic needle; and this relation is maintained during each act of vision, whatever be the motions of the head or of the object at the time. If the head is moved towards the right shoulder, the superior oblique muscle of the right side acts sufficiently to counteract the effect upon the eye until a distinct perception has taken place. The muscle is then relaxed, and again brought into action, so as to allow a succession of distinct visual impressions, as has been illustrated in the example of the carriage wheel. When such a motion, or series of motions, is produced in one eye by the superior oblique, exactly corresponding results take place in the other eye by the action of the inferior oblique. These two muscles consent in their actions as if they were one, and yet we find that they derive their nervous influence from separate sources. Now, as we find every part of the living body fitted by its structure to the exact functions which it has to perform, we cannot doubt that a meaning is contained in this peculiar adaptation, which obtains throughout the whole class of animals that have moveable eyes. What the true interpretation of this particular disposition may be, I will not at present undertake to determine. But I may remark, that as the oblique muscles (taken together) have a double supply of nervous influence, so have they a two-fold office.[1] In all eyes that I have had an opportunity of examining, the oblique muscles embrace the eye, and have evidently the power of compressing it. In the cod and jack and other fish, the oblique muscles have a somewhat different relation to the eye to that which obtains in the human subject. They arise from the anterior and inner part of the orbit, and passing backward and outward, nearly in the transverse diameter of the eye, are inserted with the superior and inferior rectus into the upper and under part of the globe. The recti muscles arise very far back in the orbit, and proceed forward as well as outward to their connexion with the eye. They therefore meet the oblique muscles above described nearly at right angles. In birds, the superior oblique muscle arises from the anterior and inner part of the orbit, passes backward and outward, and expands into a flat triangular muscle, being inserted into the most projecting part of the upper surface of the eyeball. The inferior oblique is smaller, but takes the same direction as the superior oblique, and is inserted in a similar manner into the lower part of the eye. In quad-

[1] Sir C. Bell has with much justice insisted on the consent which obtains between antagonistic muscles, and has shown by direct experiment, that if a muscle contracts its opponent will relax, and *vice versâ*. Two muscles, supplied by different nerves, may thus have a mutual influence upon each other, and concur in performing a double function.

rupeds, the oblique muscles have the same origin and disposition as in man, but, owing to the eyes being situated at the side instead of the front of the head, their mutual relations are somewhat altered. In nearly all animals, they proceed more directly across the globe of the eye than in man.

It may be stated generally, that in those animals in which the socket of the eye is large, as compared with the head, and the eye directed laterally, the superior oblique muscle arises from the margin of the orbit, and proceeds backward and outward, or, in many instances, directly outward to its insertion; whereas in those where the socket is comparatively small, it arises with the recti from the bottom of the orbit, and after passing forward, is reflected through a pulley to its insertion. Whatever diversity there may be in the attachment and disposition of this muscle, it has a distinct nerve appropriated to its sole use in all classes of animals. Had its action been exactly similar to that of the inferior oblique, a branch of the same nerve might have supplied both. The superadded nervous influence implies a superadded function. Now the only action that the oblique muscles can have in all animals, besides that of rolling the eye in its socket, is to compress the eyeball. For although in some animals, from their oblique direction, they might be supposed to influence the direction of the eye, this would not be the case in others. In the swan, for instance, the so-called oblique muscle runs directly across the eye in its transverse diameter. From the observation of the actions of this muscle in man, its use has been assigned, by no ordinary authority, to be that of raising and dragging the eye, in conjunction with the changes to which the other features are subjected "in bodily pain, in agony of mind, and in all this class of passions." But not to mention that there are whole classes of animals in whose features no such expressions ever are recognised, the disposition of this muscle in fishes and birds entirely forbids the idea of any such office being assigned to it.

Although we cannot therefore determine satisfactorily the exact relations of this muscle, yet we infer from what has been said, that it has a twofold action: first, that of rolling the eye; secondly, that of compressing it so as to alter its focal length. But as other explanations equally ingenious have been maintained with reference to the mode in which the eye adapts itself to vision at different distances, we would not here enter upon the discussion, as to whether this effect may not also be produced by other means, but simply observe that the oblique muscles, taken together, have a double function, and a double supply of nervous power. Dr. Hosack, in a paper published in the *Philosophical Transactions* in 1794 (part II, page 222), observed, that external pressure was capable of altering the focal length of the eye, so as to adapt it to vision at different distances. "With a speculum," he says, "I made pressure upon my eye while directing attention to an object twenty yards distant, and saw it distinctly; but endeavouring to look beyond it, everything appeared confused. I then increased the pressure considerably, in consequence of which I was enabled to see objects distinctly at a much nearer than the natural focal distance; for example, I held a book before my eye at the distance of two inches. In the natural state of the eye I could neither distinguish lines nor letters, but on making pressure with the speculum, I was enabled to distinguish both with ease."

Dr. Porterfield[1] objects to this explanation, that in the jack the oblique muscles "are both situated on the under side of the eye, where they decussate each other in the form a cross", and he therefore argues that the disposition of these muscles is not such as to allow them to compress the globe of the eye. "Had they been so disposed as to embrace the globe in the form of a ring, their contraction might then have squeezed the eye into an oblong form." Having repeatedly dissected the eye of the jack, I am enabled to say positively that the oblique muscles have the very disposition which Dr. Porterfield is here contemplating. His assertion respecting their decussation below the eye, has evidently arisen from mistaking the inferior rectus for one of the oblique muscles.

In all birds, the eye is embraced in like manner, in its transverse diameter, by the two oblique muscles; and when the eye is directed towards the beak, it comes more fully within the grasp of these muscles than at any other time. It is obvious, that in the act of feeding, and using their beaks for other purposes, birds require distinct vision of objects situated very near the eye; and it is equally obvious that rays of light, proceeding from a point near the extremity of the beak, would diverge before they entered the pupil, and would consequently form an image, or come to a focus, at a greater distance behind the lens, than if they had been parallel before they entered the eye. The range of vision in birds, both with regard to near and distant objects, is probably greater than in any other class of animals, and in them, as in fish, the oblique muscles are always well developed. These considerations lead us towards the solution of the question which has been asked for some hundred years past, namely, why the superior oblique muscle has one nerve distributed exclusively to it; and why that nerve, having a separate origin, and giving off no twig or branch, is sent into the orbit where there are already so many nerves? There may be, and probably are, some finer means of adjustment of the eye to vision at different distances within the organ itself, but we cannot but associate the function of this nerve, which is found in all animals that have moveable eyes, with the means by which such adaptation is produced.

Another adjustment of the eyes, which takes place as rapidly as does that of its focal length, occurs in the adaptation of the axis of the eyes to meet upon any object to which attention is directed. Here, again, we have a special action to be provided for, and a special nerve distributed to one of the muscles concerned. It is worthy of remark, that in this case, as in that of the oblique muscles, one muscle only is supplied by the special nerve, although two muscles (the internal and external recti) are equally concerned in the action. As we have a twofold motion to be provided for, (namely, that of the two eyes together, while their axes remain in the same relation to each other, and also that whereby the relation of the axes is altered, as in looking from a distant to a near object), so we have a twofold supply of motive nervous power.

The external rectus is supplied by the sixth nerve, which is almost

[1] PORTERFIELD on the Eye, vol. i, p. 424, *et sequent.*

exclusively distributed to it; and the internal rectus is supplied by the third nerve, which also supplies the other muscles of the eye. We therefore regard the ordinary motions of the eyes, while they act in concert, as under the influence of the third nerve, and their different degrees of divergence and convergence we regard as controlled by the sixth nerve. In every act of vision, therefore, there are no less than three distinct motor nerves employed, each of which conveys its mandate with a rapidity and precision of which we have not the means of forming even an accurate conception.

The muscles connected with the eye are peculiar in having the nerves which supply them with motive energy entirely distinct in their origin and course from those which supply them with sensation; and are also peculiar, as we have seen, in having their actions controlled and regulated rather by the sense of sight, than by the sensation which usually presides over muscular action. This peculiarity of disposition displays to us in a wonderful manner the care that is taken to supply every muscle (and every fibre of a muscle) with nervous influence adapted to its peculiar office. In ordinary muscles, the motive power and sentient or regulating influence are communicated through one nerve; and it is not so easy to trace their mutual relations and dependencies, as when these functions reside in different nerves. And although the mode in which the nervous energy is developed is quite as wonderful in the former case, it is more readily appreciated by us in the latter.

We have seen that in every distinct act of vision, the eyes have not only to be directed to their object, but their focal length has to be precisely adjusted; and that the sensations of the retina are the means by which these actions are governed. The rapidity with which they take place is such, that no one probably, unless directing especial attention to the point, would appreciate the interval which elapses between two distinct impressions as the eye runs over the surface of any object, and receives in succession the reflection of its different parts; and yet, for each such impression the sensation of the precise adaptation required has to be received by the retina, transmitted through the optic nerves, and, reflected again through the nerves of motion distributed to the muscles of the eye. The rapidity of such communications is truly electrical. One of the most striking instances of the rapidity of such communication of sensation, and consequent action of the muscles, is afforded in those instances where gunpowder accidentally explodes in a person's face. The eye takes cognizance of the flash, the information is transmitted to the brain, thence along the facial nerve through a circuitous route in the petrous portion of the temporal bone, to the outside of the face; and the circuit is completed, and the eyelids closed, before a single particle of the powder reaches the surface of the eye.

13, Dover Street, Piccadilly, July 1851.