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ON

SINGLE AND CORRECT VISION,

BY MEANS OF

DOUBLE AND INVERTED IMAGES ON THE RETINÆ.

BY

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By Order of the Council,

JOHN ROBISON, SEC.

ON

SINGLE AND CORRECT VISION, &c.

In entering on a question which may be said to occupy a portion of the debateable land between Physiology and Metaphysics, it seems, in the first place, necessary to state with precision the nature of the difficulty, which has long been felt on this subject, and endeavour to determine the degree to which it is reasonable to expect, that this difficulty may be removed; and on these points there is such a discrepancy of opinion, even among the latest and most esteemed authors, as obviously to make farther inquiry desirable.

No one can be more thoroughly convinced than I am, of the utter futility and absurdity of all attempts "to shoot the gulf which separates the sensible world from the sentient soul." In all our inquiries in the Physiology of the Nervous System, as connected with mental acts, we must keep in mind, that the end of these inquiries can only be, to determine the physical conditions under which the different mental phenomena take place; and those under which, when they have taken place, they affect the different organs of the body. The question, how it comes about, that when those conditions are fulfilled, these results follow, must be held, in every case, to be beyond our powers.

But as it is clearly in our power to ascertain the *general* conditions under which any mental phenomena are connected with a living body, so it may also be in our power to ascertain the *special* conditions under which any particular idea, or other mental act, takes place; and particularly, to determine the exact sensations with which any particular notion formed in the mind is naturally

connected, or by which it is suggested; and, in a case where the very same notions seem to be suggested by different sensations, we may expect to arrive at the knowledge of the manner, in which the intimations acquired by the different senses are made to correspond.

When the attention is fixed for the first time on the fact, that, although the notions which we acquire of the number and position of external objects, during the ordinary exercise of the sense of sight, are correct, yet the images on the retinæ, which are the essential conditions of our seeing any one of these objects, are double, inverted, and reverted,--the natural inference certainly is, that some explanation should be sought, and may be had, of so singular an anomaly. But a little reflection will shew, that our notions of the number and position of objects are not connected *merely* with the exercise of the sense of Sight, but very much with that of Touch. And when we find it stated by many philosophers, that we have *no notions* on those points naturally and originally connected with Sight, and that it is only by *experience*, and by association with the notions acquired by Touch, that we learn to form judgments of the number and position of objects by the eye—we must admit, that it is only by appeal to facts, not by any reasoning *à priori*, that the truth or falsehood of this doctrine can be determined. We must therefore satisfy ourselves, that number and position are original, not acquired, perceptions of the eye, before we are entitled to ask for an explanation of single and correct vision, by double and inverted images.

The late Dr Brown was so confident of the perception of the number and position of visible objects being acquired only by association or custom, that he thought himself justified in dismissing the subject with the following observations: " In the single vision of the erect object, from a double image of the object inverted, there is nothing at all mysterious to any one who has learnt to consider, how much of the visual perception is referable to *association*. If the light reflected from a single ob-

ject *touched by us*, had produced, not two merely, but two thousand separate images in our eyes, erect or inverted, or in any intermediate degree of inclination, the visual feeling thus excited would still have *accompanied the touch of a single object;* and if only it had accompanied it uniformly, the *single* object would have been suggested by it, precisely in the same manner as it is now suggested by the particular visual feeling that attends the double inverted image."*

But, with all deference to this illustrious metaphysician, I will take the liberty of stating, that this view of the subject had been previously fully considered, and, as far as I can judge, completely set aside by Dr Reid, at least in reference to single vision by two images on the retinæ; and that, not by any abstract reasoning, but by appeal to facts.

If it were only by experience, and association with the perceptions of touch, that we learned that any object placed before the eyes, and seen by two images, is nevertheless single, it seems *primâ facie* reasonable to conclude, that we should never see an object double, which we know by touch to be single; whereas we all know, that if, by pressure on the ball of one eye, or by any other means, we direct the axes of the two eyes to different points in an object, we immediately see it double, and cannot, by any means, avoid seeing it double, so long as that condition of the eyes continues, notwithstanding the full conviction, derived from touch, of its being single.

The only answer that I can conceive to this is, that the association, by which we are informed of an object of sight being single, is formed with the natural and healthy state of the vision of that object, when the axes of the two eyes are directed to the same point in the object, and its images are formed on *corresponding points* of the retinæ of the two eyes; and that when its images are formed on dissimilar points of the retinæ, the diffe-

* Lect. 29.

rence of the sensation excited, from that which is usually felt, is at once perceived, and the association, by which its unity had been made known to us, is broken.

But this answer does not apply to the cases stated on this point by Dr Reid, of persons who had *squinted from infancy*, and in whom, therefore, the association of single objects must have been formed with images on *dissimilar* points of the retinæ, and must have been broken when the images of an object were formed on corresponding points. These persons, according to the theory in question, should have seen objects single when they squinted in their usual way, and not when the axes were brought to bear on the same point, in a way quite unusual to them. But the reverse was the fact. They saw double when they squinted (excepting in particular positions of the eyes, when, as Dr Reid supposed, one of the images was formed on the well known insensible spot on the retina); and "when they learned to direct both eyes to an object, they saw it single."

I can myself confirm the observations of Dr Reid from pretty numerous trials on persons who habitually squinted; in which it always appeared, if the vision of both eyes was tolerably good, that, when the attention was fairly fixed on the sensations of both eyes, single objects held directly before the face were seen double, and again, that different and distant objects held carefully in the direction of the axes of the two eyes, seemed to coincide.

Again, says Dr Reid, "from the time we are capable of observing the phenomena of single and double vision, *custom* makes no change in them. I have amused myself," he adds, "with such observations for more than thirty years; and in every case, wherein I saw the object double at first, I see it so to this day, notwithstanding the constant experience of its being single. In other cases, where I know there are two objects, there appears only one, after thousands of experiments.

"Effects produced by habit must vary, according as the acts by which the habit is acquired are more or less frequent; but

the phenomena of single and double vision are so invariable and uniform in all men, and so exactly regulated by mathematical rules, that I think we have good reason to conclude, that they are not the effect of custom, but of fixed and immutable laws of Nature."*

In fact, it is a very imperfect and inaccurate expression of the phenomenon in question, to speak of it merely as single vision resulting from two images on the retinæ. The precise expression of the fact, as fully illustrated by Dr Reid, is, that when images are formed *on corresponding points of the retinæ*, they appear as one; and *in all other circumstances they appear as two*, as they really are; and this general fact holds good, equally in the case of those, in whom the experience of the sense of Touch habitually *opposes* the inference drawn from Sight, as in that of those in whom it habitually *confirms*, and has been thought to suggest that inference.

The difficulty which is presented by the inversion of the images on the retina is, I think, most correctly expressed thus: The sensations, both of Sight and of Touch, obviously differ from one another in position; and by doing so, both convey to us intimations of the situation of external objects. But the judgments which we form of the relative position of objects, or of the parts of an object, from the relative position of the impressions which they make on the sensitive surface of the *retina*, are just the reverse of those which we form of the relative position of objects or their parts, from impressions made on the sensitive surface of the *skin*. Thus, if two impressions are made on the upper and lower portions of the eye-ball, and felt through the fifth nerve, the inference immediately drawn is, that the upper impression is from a higher object, and the lower from a lower; but if two impressions are made on the upper and lower part of the retina, and felt through the optic nerve, the inference

* Inquiry into the Human Mind, &c. Sect. 17, *ad fin.*

is, that the impression on the upper part is from the lower object, and that on the lower part from the higher. Why this difference should exist, is the point in question.

It is perhaps difficult to find decisive evidence in the human body, that the intimation of the position of the erect object, given by the inverted image, is *originally* correct, and in harmony with the intimation given through the sense of touch, before experience and association can have time to operate; but it is unnecessary to argue this point, because it is allowed even by Dr BROWN, that, in the case of many of the lower animals, there is an original perception of the true position of objects, acquired by the sense of sight; so that those who have so humble an idea of their own powers of visual perception as to believe, that it is only by experience and association that *they* learn to judge, by the eye, whether an object is erect or inverted, may acquiesce in what is here to be said, as applicable to the lower animals.

But it is farther necessary to premise here, that, while some philosophers have thought it unnecessary to seek for any explanation of correct vision by double and inverted images, because they believe that the eye gives *no original intimations* whatever as to the number or position of objects,—others are equally convinced of the futility of the inquiry, because they maintain, that *the eye does give intimations* which necessarily imply, that the objects, of which inverted images are formed on corresponding points of the two retinæ, are erect and single.

This is done by reference to the *Law of Visible Direction*, fully illustrated by Dr REID, and many others, according to which, every object appears to be in the direction of a straight line drawn perpendicularly to the retina at the point where its image is formed. This law has not been similarly expressed by all who have referred to it; but the terms here used are those employed by Sir D. BREWSTER and Mr MAYO. In conformity with this law, when an image is formed on a concave surface, the lower

part of that image must be referred to the upper part of the external object corresponding to it, and *vice versâ;* and again, images formed on corresponding parts of the two retinæ, and referred, according to this law, to external space, must appear to come from the same points, *i. e.* to represent the same object.

But here the question immediately presents itself, How is this law of Visible Direction originally formed in, or impressed upon, the mind? If it be thought to be acquired by experience and association, the observations already made apply to, and I think set aside that supposition. If it be thought to be independent of experience, it implies, in the first place, that the mind has an original perception of distance by the eye, *i. e.* that it is originally aware of impressions on the retina being produced by causes at a distance from the body, although it draws no such inference from impressions on the skin; whereas not only BERKELEY and his followers, but REID, and most other authors on this subject, have believed that it is only by experience that we learn that visible objects do not touch the eye; and this has been generally thought to be supported by observations on persons to whom the sense of sight has been given suddenly, and at a mature age, by couching.

But farther, this doctrine implies that the mind naturally draws an inference, not only as to the position of any impression that may be made on the retina, but as to the *direction in which the ray of light came*, that made that impression; and as that direction is not a direct object of sense, and as I apprehend that no reason can be given, why a ray should be supposed to have come in the direction of a perpendicular to the surface of the retina, rather than of any other line falling on that surface,—this theory really ascribes our perception of the true number and position of objects by the eye merely to the principle of *Intuition*, *i. e.* it merely *states the fact*, that the images formed on the retina are referred to places in the external world according to this law; and if we regard the theory as a sufficient explanation, we must regard this as an *ultimate fact* in our mental constitution.

Now, no disciple of Reid or Stewart can have any hesitation about admitting, that this principle of Intuition is part of the cause of all the information we derive from this or any other sense. I hold it to be equally certain, that we learn some things intuitively, we know not how, as that we do some things instinctively, we know not why. And, admitting the principle of Intuition, it is impossible for us to say *à priori*, without special investigation of any alleged case, how far it may extend, or how much of the information which we habitually acquire by the senses, is explicable in no other way. But it is obvious, that this must be our last resource in attempting to account for these phenomena; and it is unphilosophical to assume, that the limit to our curiosity is to be found on the very threshold of our inquiry.

Dr Reid has stated this with his usual candour and precision. After observing that *he could trace* the phenomenon of correct vision by inverted images no farther than to the law of visible direction above stated, he adds the following words, which may be taken as the groundwork of any farther speculations on this subject. "We acknowledge that the retina is not the last and most immediate instrument of the mind in vision. If ever we come to know the structure and use of the choroid membrane, *the optic nerves and brain*, and what impressions *are made on them by means of the pictures on the retinæ*, some more links of the chain may be brought within our view, and a more general law of vision be discovered."—*Inquiry, &c.* ch. vi. § 12.

I apprehend, then, that two facts are established,—are not to be explained by experience or association,—and, not being *necessarily* ultimate facts, afford a fair subject of physiological inquiry. 1. That *images formed on corresponding points of the retinæ of the human eyes, and on those only, naturally affect our minds in the same manner as a single image formed on the retina of one eye;* and, 2. That *impressions made on different points of the retina of the eye are naturally followed by inferences, as to the relative position of the objects producing these impressions, exactly opposite to*

those which follow impressions made on different points of the surface of the body.

I. Of the first of these facts, *i. e.* the single vision by means of double images, it is well known that an explanation was proposed by NEWTON, fully considered by REID, and since supported by WOLLASTON (often called the Theory of WOLLASTON, but quite incorrectly), proceeding on the supposition of a *semi-decussation* of the human optic nerves at their commissure; whereby the fibres, from the right half of the retina of each eye, go to the right *optic lobe** in the brain, and *vice versa;* the consequence of which may probably be, that the fibres which connect themselves with, or terminate at *corresponding points* of the retinæ, may originate at the *same points* in the optic lobes. If this be so, impressions made on *corresponding points* of the retinæ are in fact impressions made on the *same points* in the optic lobes; and, as they are effectual in exciting sensations in the mind, only inasmuch as they are made on the optic lobes, *they must necessarily co-operate in exciting the same sensations.*

Dr REID fairly admits that, if the anatomical part of this theory were ascertained to be correct, "it would lead us a step forward in discovering the cause of the correspondence and sympathy of the two retinæ;"—he ought rather to have said—the cause of single vision by impressions made on corresponding points of the two retinæ. I think we may add, that it is the *only step* which we can conceive to be taken, or can desire to take, in that inquiry. And I will farther venture to maintain, that a precisely similar step may be taken, even with more confidence, as to the correct vision by means of inverted images.

We must admit, that the anatomical evidence of the theory

* The term optic lobe is here used as a short expression for that portion (perhaps not yet absolutely determined) of the contents of the cranium, from which the optic nerves originate, and on which their sensibility depends.

of Newton is still defective. Several additions to our knowledge on the subject have been made since the time of Reid. 1. The supposition of the semi-decussation of the optic nerves, and consequent connexion of half of the retina of each eye with one of the optic lobes in the human body, has acquired additional probability from the observation, first applied to the subject by Dr Wollaston, of that form of temporary loss of vision formerly called *Suffusio dimidians*, in which, although both eyes are open, one-half of the field of vision disappears from the sight; which is easily conceivable on the supposition of the right half of each retina being connected with the same portion of the sensorium, and not easily understood on any other supposition.* 2. That the commissure of the optic nerves is really a partial decussation in all animals where it exists, seems to me, if not absolutely ascertained, to be put on very strong ground, by the dissections of Mayo and the observations of Serres.

Of the dissections of Mr Mayo, made after the nervous fibrils were hardened by alcohol, in the human body, we have a distinct record in his engraving of the commissure of the optic nerves (Pl. vii. fig. 3. of his Engravings; fig. 1. of the plate hereto annexed), of the accuracy of which I am satisfied, from some trials which I have myself made in the same manner, and in which it distinctly appears, that the outer portion of each optic nerve is formed by fibres proceeding forward from the outer part of the tractus opticus of the same side, and that some fibres, at least, of the inner portion of each optic nerve, have crossed over from the inner part of the tractus of the opposite side, as supposed in this theory.

The result of the inquiries of Serres on this point, in various animals, is stated as follows. He never could satisfy himself on the subject by preparations either of the human body, or others

* This affection is sometimes quite transient; but in other cases, as I have myself known, it is permanent, at least for weeks together.

of the mammalia in the adult state; but in the fœtal state, in man, in the horse, ox, sheep, rabbit, and guinea-pig, he distinctly saw the internal fibres of the tractus opticus separate themselves from the external, and traced them across from the right tractus to the left nerve, and *vice versa*. In crossing, they form a plexus, and, as the animal grows, this plexus is soon loaded with fresh deposits of medullary matter, so that the course of the fibres, distinct in the fœtal state, is hardly to be traced in the adult.

The idea that the partial decussation of the optic nerves is designed to give single vision by two eyes directed to the same object, is farther strongly confirmed by the fact, that in those animals in which this structure is generally, if not universally, found, *i. e.* in mammalia and birds, the power of directing the axis of both eyes to the same object, generally, if not universally, exists, although in many quadrupeds and most birds the object which can be thus contemplated must be at a considerable distance; whereas in those animals in which there is (generally, if not universally,) no intermixture of the filaments of the optic nerves, *i. e.* in reptiles and fishes, the eyes are so situated, as remarked by Cuvier, that any object *must* in general, and probably in most instances *can*, only be contemplated by one eye at a time.*

But notwithstanding this strong evidence of the existence of the partial decussation in the higher animals, and of its connexion with the single vision by two eyes, the foundations of the theory must be allowed to be deficient. The partial decussation of the nervous fibres will explain the single vision by two eyes only on the supposition, that the fibres which terminate in *corresponding*

* Anat. Comp. Leç. xii. Art. 2. It is true that the axes of the two eyes, at least in some fishes and reptiles, may be brought to bear on the same objects, if very distant, but as the vision of very distant objects is seldom requisite for these animals, it is probable that they are not habitually guided by simultaneous impressions on the two eyes.

points on the retinæ (at least in those corresponding points on the retinæ which can be brought to bear on the same objects), originate in the *same* points on the optic lobes. Now, in order that this may be effected, there must be a very peculiar arrangement of the nervous matter, both on the retinæ in front, and on the optic lobes behind. The entrance of the optic nerve in the human eye being considerably on the inner side of the optic axis, the separation of the right and left portions of the retina cannot take place there; the fibres on the inner side of the nerve, coming from the opposite lobe, must extend outwards as far as the central foramen, in order that all the inner half of the retina may be connected with the opposite optic lobe; and, at that central point of the retina, these fibres, or the membrane continuous with them, must be overlapped by those which come from the lobe on their own side, and form the outer part of the optic nerve. Again, the fibres passing backwards from the outer portion of the right, and inner portion of the left retina, to form the right tractus, must be there so combined, as that those which come from corresponding points in the retinæ may be implanted at the same points in the lobes. And I am not aware that these peculiarities in the course of the fibres, which the theory seems obviously to require, have hitherto been detected by any anatomist.

It is to be observed here, however, and obviates one objection that has been stated to this theory, that in the case of most quadrupeds and birds, whose eyes are generally directed widely asunder, it can only be a small segment of the outer part of the retina of either eye, which will ever be brought to bear on objects situated within the sphere of vision of the other eye; and it is only this small portion which, if the principle of single vision has been correctly stated, requires to be associated at its root with the corresponding portion of the retina of the other eye. Accordingly, in such animals, it is obviously more than a semi-decussation which takes place at the commissure of the optic nerves;

and indeed in all animals the term *partial* decussation is the more proper. In such animals, we should expect, from anatomical observation, what we find, from the effects of injury and disease, to be the case, that the vision of each eye is more dependent on the opposite optic lobe than on that on its own side. Partial decussation, according to the theory, should exist, and, as far as observations have been made, I believe does exist, in all animals which habitually bring their optic axes to bear on the same point, however distant; but semi-decussation should exist only in those, in which the natural direction of the axes is parallel.

On the whole, it may be said, that there is very strong presumption, though not absolute certainty, in favour of the doctrine of the dependence of single vision by two eyes on the partial decussation of the optic nerves.

II. The explanation, which seems to me satisfactory, of the erect vision by inverted images, was first suggested to me by Mr Dick, veterinary surgeon, and turns on the alleged fact, that the course of the optic nerves and tractus optici is such, that impressions on the upper part of the retina, are in fact impressions on the lower part of the optic lobes, *i. e.* of the sensorium, and impressions on the outer part of the former, are on the inner part of the latter; and *vice versa*.

If this be so, it appears to me, after repeated consideration, that it will furnish an explanation, and the only one of which the subject admits, of the harmony or correspondence, which I believe to exist from the first, between the intimations acquired by sight and by touch, as to the relative position of objects or their parts, notwithstanding that the impressions made by them on the external organs of sight and of touch are arranged inversely in regard to one another.

In regard to the nerves which are truly the organs of touch, *i. e.* the posterior portions of the spinal nerves, and the larger portion of the fifth cerebral, which is truly a spinal nerve, the ge-

neral law certainly is, that all impressions made on their branches are felt by us to be higher or lower, as the points of the cerebro-spinal axis, from which they originate, and on which their sensibility depends, are truly higher or lower; and if there be such a peculiarity in the insertion of the optic nerves into the cerebro-spinal axis, that its highest portion is inserted lowest, and its outermost portion inserted innermost, then the fact of impressions on the upper surface of the retina and optic nerve being felt by us as lower, and of impressions on their outer surface being felt as inner, will be reduced to the same law as regulates our perception of the relative position of objects of touch.

In all the vertebrated animals, it is well known that the optic nerves, behind the commissure or decussation, or Tractus optici, cross and embrace the Crura cerebri; and that in the Mammalia they are in connexion, behind or above the crura, with the bodies called Thalami nervorum opticorum, and Corpora quadrigemina.

It has been disputed, even lately, whether the true origin of the optic nerves in the human body is in the Thalami, as was formerly thought, or in the Corpora quadrigemina, as maintained by Gall and Spurzheim; and I have repeatedly noticed the accuracy of the observation of the late Dr Gordon, that the fibres of the tractus opticus are not merely expanded over the outer surface of the thalamus in the human body, but at various points plunge into its interior. Even those which thus dip inwardly, however, follow the same direction as the more superficial fibres, tending inwards and downwards towards the Corpora quadrigemina.

In others of the mammalia, the connexion of the optic nerves with the thalami is much more superficial; and in birds, reptiles, and fishes, it seems perfectly ascertained, that the optic lobes, in which the optic nerves exclusively originate, correspond to the Corpora quadrigemina only.

The question of the true origin of the optic nerves, however, cannot be decided merely by anatomical inquiry. It is now well

known, not only that the endowments of different nervous filaments, of precisely the same structure, and contained in the same mass, or bound in the same sheath, are often perfectly different; but even that different portions of the same nervous filaments, especially where they connect themselves with the central masses of nervous matter, may have perfectly different endowments; as, *e. g.* in the case of the fibres ascending from the Corpora pyramidalia, through the crura cerebri and corpora striata, to the bottom of the convolutions, the whole of which are continuous, but only part of which possess the power of exciting muscular contraction when irritated.

Now, if we inquire in what part of the contents of the cranium the sensations of the eye are found *by experiment* to reside, the experiments of Mayo and of Flourens, particularly those of the latter author, which were repeated before, and reported on by Cuvier, are generally regarded as affording satisfactory evidence that they reside in the Corpora quadrigemina. These bodies, and the optic nerves, appeared distinctly to be the only parts of the nervous system, the irritation of which uniformly excited the contraction of the iris, no doubt by producing a sensation of light; and the destruction of which uniformly stopped the play of the iris, and extinguished vision.*

Our business is, therefore, to learn in what manner those fibres of the Tractus optici, which can be distinctly traced into the Corpora quadrigemina, are there implanted; and when we trace the course of these fibres in the brains of the mammalia (hardened by alcohol), whether they descend on the Corpora quadrigemina from the Thalami, or pass more directly backwards below the Corpora geniculata, it seems to me quite obvious that they first turn inwards, and then enter the Corpora quadrigemina from above downwards, and are so expanded over the superior of

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* See Recherches Experimentales, &c. p. 150, *et seq.*

these bodies (the nates), that the outer portions of the Tractus pass over to the inner part of the nates, and the upper portions of the Tractus pass down to the lower part of the nates.*

In the lower classes of vertebrated animals, where the course of the Tractus opticus on each side to the optic lobe, is shorter and less winding, it is not so easy to ascertain whether the whole of the fibres passing backwards from the nerve, and turning round the crura cerebri, are inserted in the same way as in the mammalia; but that they are expanded over the optic lobes from before backwards, is easily shewn, and if we can trust the representations of SERRES, the mode of their implantation into the optic lobes is quite in conformity with what we observe in the Mammalia.†

Now, there is no such contortion or involution of the nervous filaments of the fifth, or of any other nerve of the symmetrical system, where it is implanted in the cerebro-spinal axis, and so constituted a nerve of Touch; and from this I think it clearly follows, that although the impressions made *on the retina*, by the different parts of an object, are situated in regard to one another in the *inverse* order of those made on the surface of the body, yet the impressions made, *through the retina* and optic nerves, on the *cerebro-spinal axis*, are *in the same order*, as those made through the nerves of touch, on that central portion of the nervous system, on which the sensibility of all nerves depends; and therefore, that the notions which we form of the relative position of the parts of objects, by the senses of sight and of touch, will naturally correspond.

But another difficulty here presents itself. Although we understand, from what has been stated, in what manner the impres-

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* See Plate XVI. Fig. 2. of this volume.

† See Anat. Comp. du Cerveau, Plates vi. vii. Figs. 149, 151, 159, 165, 170, 181, 188–89, and 193; and Pl. XVI. Fig. 3. of this volume.

sions, made *on each of the optic lobes*, by the images on the retinæ, correspond with the real position of the parts of external objects, which these images represent; yet, in the case of man, and of all other animals, in whom the partial decussation of the optic nerves exists, and in whom, if that form of structure has been rightly explained, *both optic lobes* are concerned in vision even by one eye, (the right lobe in the vision of the right division of the retina, and the left lobe in that of the left), only one portion of the field of vision, even of one eye, produces any impression on one optic lobe; and the *left portion of the field of vision*, being represented (by the laws of light) on the right division of the retina, makes its impression on the *right optic lobe*, while the right portion of the field of vision, represented on the left division of the retina, impresses the left optic lobe; therefore, although the individual parts of each of these impressions are in the right order, yet the two impressions are transposed; and both are necessarily, at one and the same moment, objects of attention to the mind.

Now, if it be true, as is here supposed, that the impressions on the eye, by which we are informed of the relative position of objects, harmonize with those made on the sense of touch, only because when transmitted to the optic lobes they are arranged in the real relative position of the objects exciting them, this transposition of the impressions made by two distinct portions of the field of vision, even of one eye, appears fitted to deceive us, and I believe would do so, were it not compensated by another piece of structure, the use of which has long puzzled physiologists, and which I do not remember to have seen connected by any one with the sensations of the eye, viz. the Decussation at the Pyramidal bodies;* whereby, as is generally believed, the whole common sensation, and the whole voluntary motion, of the left half of the body, are put in connection with the right half of the brain, and those of the right half of the body with the left half of the brain. Therefore, while man, and all other animals, that have the power of looking directly forwards, see what is to their

* Plate XVI. Fig 4.

left when doing so, only by their right optic lobes, so they feel and move, on their left, also by the right hemispheres of their brains. And the sensation and motion of the left sides of their bodies are put in connection with the right sides of their brains, only because the laws of light necessarily imply, that the images of whatever lies to their left in the external world, should be formed on the right side of the retinæ of their eyes, and impress their right optic lobes.

If this be the true use of the decussation at the pyramids, the following consequences appear naturally to follow:—

1. That this piece of structure will be found only in those animals which are, more or less, in the habit of directing both eyes to the same object.

2. That, where it is found, there will be found also the partial decussation of the optic nerves, connecting each eye with both optic lobes, and each optic lobe with both eyes.

3. That where the decussation at the pyramids exists,—as the sensation and motion of each side of the body will be dependent on the opposite side of the brain,—injuries of either side of the brain, or in general of the parts superior to the decussation, if they produce palsy, will produce it on the opposite side of the body.

4. That where the decussation at the pyramids does not exist, this crossing of the effect of an injury of the brain to the opposite side of the body will not be observed.

Now, all these things are so; at least, according to the most general statements of accurate observers, certainly unconnected with the theory which is here advanced; and it seems to me extremely improbable that these coincidences should have existed, if the piece of structure in question had not been designed for the purpose, and had the effects now stated.

The decussation at the pyramids exists in the mammalia and in birds; but the number of crossing fibres becomes less in the lower parts of the scale, as does the size of the cerebral lobes, in proportion to the spinal cord. In reptiles and fishes it does not exist.* In the two former classes the power of directing the axis of both eyes to the same object, exists, although in the case of many quadrupeds and most birds, that object must be very distant. In reptiles and fishes, the eyes appear to be dissociated from one another, and directed either laterally, or vertically upwards, in such a manner that they evidently regard objects, in general, only with one eye at a time.†

In the mammalia and birds, the commissure and partial decussation of the optic nerves are found; but in reptiles and fishes there is the complete decussation and no commissure.‡

In the human body, it is well known that the usual effect of injury of the brain or cerebellum, when it produces palsy, is seen on the opposite side of the body; but the effect of injury of one side of the spinal cord, even in the neck, is seen on the same side of the body; and in the experiments of Flourens, the *crossing* influence of injuries was uniformly seen in the mammalia and birds, when they were inflicted any where above the decussation at the pyramids, but not when they were below this point. In reptiles and fishes, no crossing influence, and indeed hardly any influence, on sensation or voluntary motion, from injury of contents of the cranium, could be observed.§

I do not, however, offer this speculation as altogether satisfactory or free from difficulties; and two difficulties, in particular, present themselves so obviously as to demand notice.

1. It may be said, that, in the case of reptiles and fishes, although the impressions made on each optic lobe may be in the

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* Cuvier, Rapport sur l'Anat. Comp. du Cerveau, &c. par Serres, in latter work, pref. p. 26.

† Cuvier, Leçon 12, Art. 2.

‡ Serres, p. 326, *et seq.*

§ Recherches Experimentales, &c. p. 121.

true position of the objects whence they proceed; yet, as the optic nerves decussate completely, the vision of the left eye, and therefore of objects on the left side of the body, will be dependent on the right optic lobe, and *vice versa*. Here, it may be said, there is an apparent cause of discord between tactual and visual impressions; yet there is no decussation at the Corpora pyramidalia to compensate for it.

I believe the true answer to this to be, that as the eyes of these animals, in general, cannot be directed to the same point, and as any object, accurately observed, is contemplated only by one eye, so their attention is never fixed simultaneously on the sensations of both eyes; and when we attend to our own sensations, when we produce artificial squinting, we shall see no difficulty in this supposition. What makes it necessary, as I conceive, that the decussation at the pyramids should exist, to preserve harmony between the intimations of sight and of touch, is not the circumstance of the visual impressions from objects on the left side of the body being made on the right optic lobe, but the circumstance of the impressions made on both optic lobes concurring in producing one sensation, on which the attention is necessarily fixed; and it is where both optic lobes are found to be concerned in vision, even by one eye, that this structure is therefore to be expected.

2. When it is said that the decussation at the pyramids transfers the sensation and motion of the right side of the body to the left side of the brain, the well known objection immediately presents itself, that the sensitive and motor nerves of the *face* arise higher than that decussation; and therefore that if this piece of structure explains the harmony of impressions on the retinæ, with those on the body and limbs, it leaves unexplained the still more remarkable fact, that impressions on the skin of the *left* side of the face are felt to belong to the same side of the body, as impressions on the *right* side of the retina, and therefore on the right optic lobe.

In answer to this, I would observe, *first*, that although there may be an anatomical difficulty in understanding *how* the sensation and motion of the left side of the face are put in connection with the right side of the brain, yet observation of the effects of injury or disease demonstrate that they *are* in connection with it; the palsy depending on injury or disease of the right side of the brain extending very generally to the left side of the face, as well as of the body. And *secondly*, I would say that there is no great difficulty in understanding that this should be the case, if we suppose, as Mr MAYO appears inclined to do,* that the true origin of the nerves is in those columns of the cerebro-spinal axis which do not decussate (and this is pretty certainly the case as to the fifth nerve, which is easily traced down into the spinal cord behind the Corpora pyramidalia), and that the decussating fibres of the Corpora pyramidalia are not to be considered as the continuation of the columns of the spinal cord, but as the cords of communication between these columns, and the masses of the brain and cerebellum.† If this be so, it is easy to conceive, that an injury of the right side of the brain, transmitted through these cords of communication, should strike downwards to the left side of the body, and upwards to the left side of the face in palsy; and that, in the natural state, the sensation and motion of the left side of the face, as well as trunk and limbs, should be in connexion, although by a circuitous route, with the right side of the brain; and therefore in harmony with impressions on the right optic lobe.

If the foregoing speculation be just, it would seem that the structure to which the attention of physiologists was first directed by NEWTON, is only a part of the arrangements, by which the in-

* Outlines of Human Pathology, p. 202.

† "The two cords of the spinal marrow do not cross, but merely the middle or pyramidal fasciculi of each, which give origin to the Crura cerebri by expanding and becoming broader."—*Tiedemann's Anatomy of the Fœtal Brain, Translated by Bennett*, p. 144. I am aware of the difficulty of tracing the course of the fibres at the medulla oblongata, and what Sir CHARLES BELL describes, I believe correctly, decussating fibres behind the pyramids; but all are agreed that there are fibres in this part which do not decussate.

timations given by the sense of Sight are made to harmonize with those which result from that of Touch.

When we reflect on the importance and pre-eminence of that sense, by which we are placed in relation almost with the Infinity of Space, we should bear in mind at the same time, that the conditions of that sense are necessarily put in dependence on the laws of Light; while the sense of Touch, to which we are indebted for our most accurate knowledge of things on the Earth's surface, is altogether independent of those laws.

In order that the intimations given by these two senses may correspond with one another, it would appear, *first*, that certainly in some, probably in all animals, the structure of the optic nerve brings the impressions, which form inverted and reverted images on the retina, into the same order on the sensorium, as those which might result from the touch of the same objects; *secondly*, that in those animals which can direct both eyes to one point, the partial decussation of the optic nerves, generally, if not universally present, enables the images produced by an object on the corresponding parts of the retinæ of the two eyes, to co-operate in producing one impression on the sensorium, and one sensation in the mind; and *lastly*, that the decussation at the pyramidal bodies enables those animals to acquire correct information as to objects of sight, from impressions made by them simultaneously on both optic lobes, *i. e.* on both sides of the sensorium, notwithstanding that the impression on each side of the sensorium comes from the opposite side of the object in view.

Nothing is farther from my intention than to represent this subject as exhausted, or these conclusions as ascertained; but in the present state of our knowledge, I think it may be said, that the inquiry has led to a *probable* solution of two difficulties, long felt in Physiology,—the cause of single and correct vision by double and inverted images, and the use of the decussation at the pyramids. And if the theory shall be found to be incorrect, it may still be of use, by acting as a stimulus, and to a certain degree as a guide, to farther inquiry.

EXPLANATION OF PLATE XVI.

FIG. 1. Commissure of the optic nerves in the human body, examined after the nervous fibres had been hardened by alcohol. From MAYO's Engravings. A A, Optic nerves. B B, Tractus optici, or continuation of the nerves behind the commissure. C, Semi-decussation.

FIG. 2. Course of the Tractus optici, examined after similar preparation, in the sheep. A, Part of the right hemisphere of the brain. B, Olfactory lobes. C, Right Tractus opticus just behind the commissure. D, Crus cerebri. E, Tuber annulare. F, Right Tractus opticus cut across and torn backwards, as it expands upon and winds round the Crus cerebri and back of the Thalamus nervi optici, H, to be implanted on G, The upper portion of the right division of the Corpora quadrigemina, or optic lobes. Part of the fibres at this, their posterior termination, are turned back, to shew that those which lie lowest in the Tractus opticus are implanted in the highest part of the optic Lobe, and those which lie on the inner side of the former, are implanted in the outer side of the latter. I, Medulla oblongata. K, Cerebellum. L, Implantation of the fifth nerve (*i. e.* the nerve of touch of the face and eye) on the side of the tuber annulare, in which no such contortion is observed.

FIG. 3. Arrangement of the fibres of the optic nerves as they are implanted in the optic lobes of the fish, from SERRES' Anat. Comp. du Cerveau, &c. A, Cerebral lobes. B, Optic lobes laid open from behind. C, Cerebellum.

FIG. 4. Decussation of the fibres which descend from the brain, through the Crura cerebri and Corpora pyramidalia, to the spinal cord in the human body; found also, in a greater or less degree, in all the mammalia and birds, therefore coexistent in the Animal Kingdom, with the partial decussation of the optic nerves (Fig. 1). A, Corpus olivare. B, Corpus pyramidale. C, Decussating fibres. D, Spinal cord.

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Fig. 1.

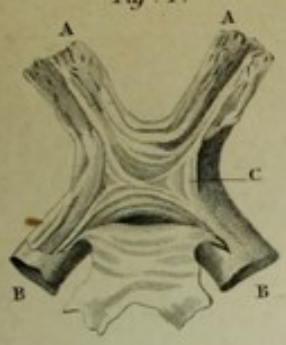

Fig. 3.

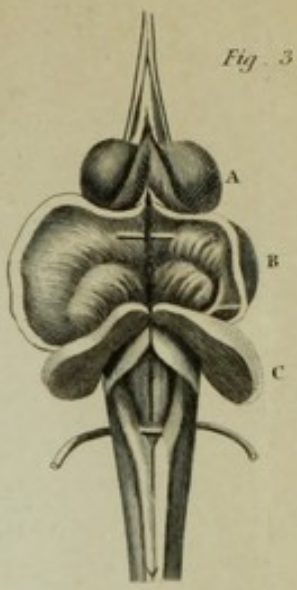

Fig. 2.

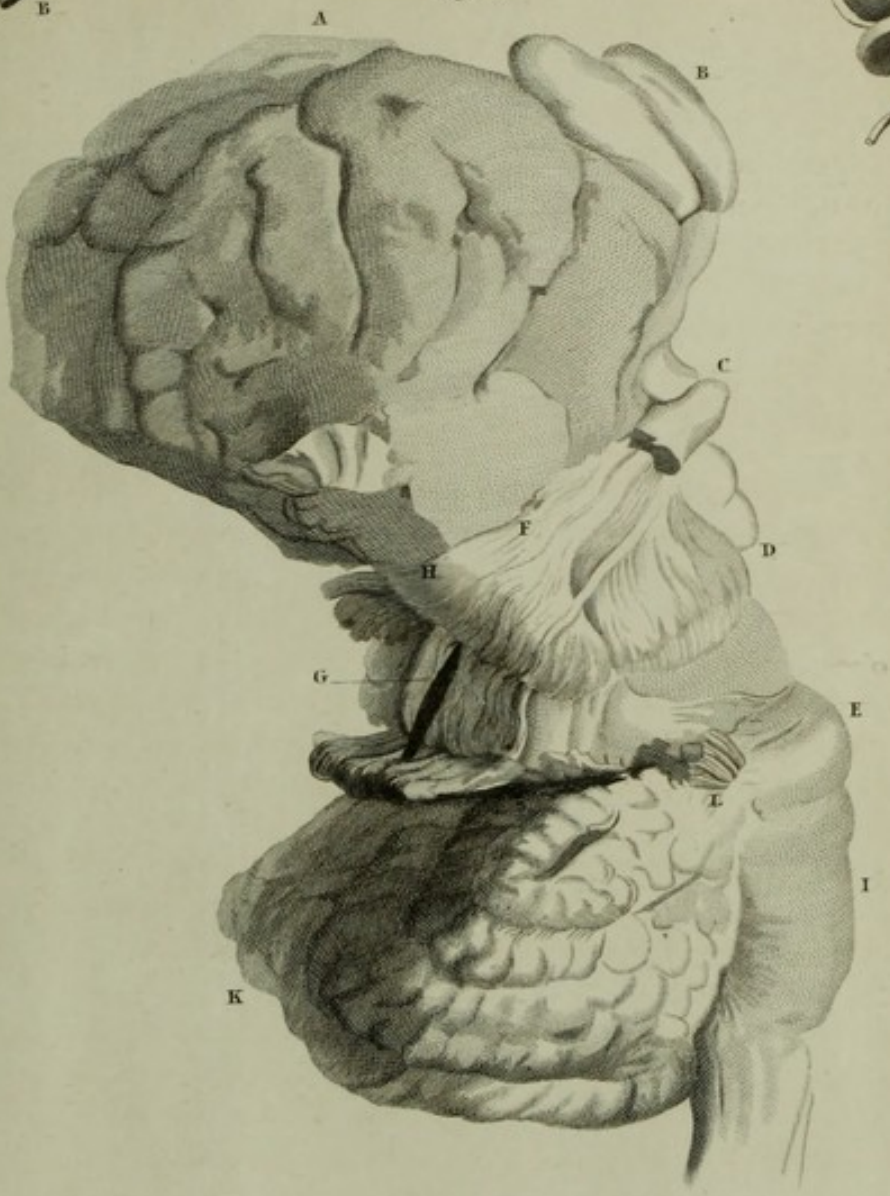

Fig. 4.