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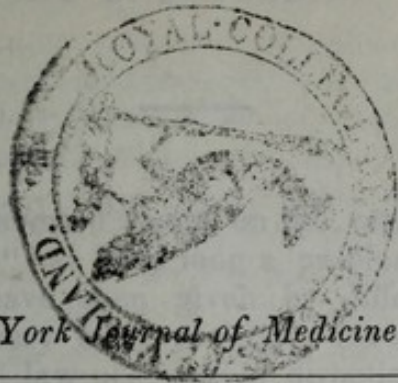
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[From the *New York Journal of Medicine* for November.]

ERECT VISION

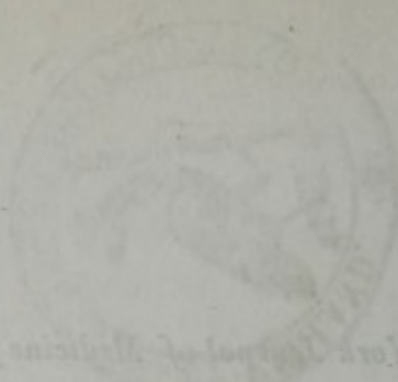
FROM AN

INVERTED IMAGE.

BY

B. F. JOSLIN, M.D.,

OF NEW YORK.



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To determine how an inverted image on the retina occasions a perception of an erect object "has been long a problem among the learned."* Various explanations have been given by different physiologists and philosophers. The theory most generally received at the present day, that founded on the law of "visible direction."† In this theory it seems to be assumed as an ultimate fact, that the mind perceives what direction is perpendicular to the retina. Some are satisfied with assuming, no less gratuitously, that we have a direct perception of the direction in which the rays of light emitted from objects come to the eye; as though the mind could, by a magical exploring power, travel out of its habitation, and feel along the course of the rays. We find such views, not only in popular works on natural philosophy; but Magendie—writer seldom satisfied with superficial or inexact views—remarks, that "We believe, instinctively, that the light passes in a right line, and that this line is a prolongation of that pursued by the ray which has entered the cornea." If others refer this perception of the course of the rays to experience, the explanation is vague; the mode in which experience determines this has not been satisfactorily explained. If they deny any power of determining direction by the eye, independently of the sense of touch, they overlook the muscular sense of the ocular muscles. Some have maintained that infants see objects inverted. Others have pronounced erect vision from an inverted image, an inexplicable phenomenon. In this last class we may place Prof. Dugald Stewart and Dr. Abercrombie. The latter remarks that, "All that can properly be said appears to be, that such is the constitution of our nervous system." Are we then, with these philosophers, to regard this as an ultimate fact, one not susceptible of being analyzed and referred to the same class with others more simple and more general?

It is in the first place necessary to state that the subject requires to be considered in a twofold view—viz., First, in regard to the relative position of objects as compared with the earth or with the observer at rest; secondly, as to the relation between this position and the direction of our own voluntary motions.

Let us first consider it in the first sense, which appears to be that in which the problem is generally understood by those who have attempted solution, as well as by those who find a difficulty in conceiving how an inverted image can do otherwise than give a perception of an inverted object.‡

* Brewster's Optics.

† Ibid.

‡ Even Magendie, who considers it an assumption wholly unsupported by proof, that infants see objects reversed, seems nevertheless tacitly to admit its possibility.

When we have a just idea of the signification of the terms erect and inverted, it will not be difficult to discover that the perception of erectness in an object involves a principle which is more elementary, and which is not confined to vision. If we show that the same principle extends to the sense of feeling, we shall have advanced at least one step in the investigation of this apparent anomaly.

Now considered without any reference to the course or bearing of our voluntary motions—i. e., reference to the particular direction in which the eye or hand is to be moved to trace it—an object appears erect or inverted only with reference to some other object, with reference to the earth for example, or with reference to the body of the observer. I am conscious of being erect, and if I perceive another individual in the same position with myself, I perceive him to be erect also. Now the obscurity in which the theory of the perception of position has appeared to be involved, has resulted from the confusion which has been introduced by comparing one object with the image of another, instead of comparing objects with objects, and images with images, or in other words, from comparing the perception of one object with the sensation produced by the image of another, instead of comparing perceptions with perceptions, and sensations with sensations. If I am standing, and a man stands erect before me, I do not compare the sensation produced by his inverted image with the perception produced by the inverted image of my own body; but I compare the sensations produced by the two images.

It is easy to conceive that our minds might be so constituted, that the impressions made on any two contiguous points of our organs of sense might be attended by a perception of contiguity in the objects, and the distance between the points impressed—i. e., the intervention of intermediate points of the organ—might be attended with the perception of distance between the objects. Surely no one can conceive any reason why an impression on two contiguous points should give a perception of remoteness. If it gives any perception of location, it must be that of contiguity. This, if a principle, would suffice for showing the correctness of our earliest notions of the relative position of external objects. But instead of viewing this as an ultimate principle, I derive it from others more elementary, and consider the perception of angular distance and in one sense that of contiguity, as dependent on muscular feeling maintaining, however, that after a very short experience, simultaneous impressions on contiguous points give a perception of contiguity, and those on remote points a perception of remoteness, and that consequently it is impossible that erect objects could appear inverted when their parts are viewed either successively or simultaneously. To leave nothing vague, let us consider what is the fundamental idea of contiguity and a preliminary to it—of contact. If I place my finger so near an object as to feel its resistance, I touch it. This is my fundamental idea of contact, yet I can conceive that a closer proximity might be required in order that a being differently constituted should receive the same sensation and I believe that no two particles of matter are in absolute contact. The above, therefore, is not absolute contact, strictly and mathematically considered, but it is physical contact, i. e., such a degree of approximation as produces on us a sensible repulsion.

Now, to examine an object by the sense of feeling, requires contact with the organ of feeling. If I move my finger continuously along the surface of an object, so as to be in contact with its different points in suc-

ssion, my muscular sense informs me not only of its repulsion, but of the different degrees of motion requisite for the examination of different parts. Any two parts whose successive examination by the same point of the finger requires no movement, or the least appreciable movement of the finger, I consider contiguous. This is the elementary idea of contiguity, as perceived through the medium of feeling.

Let us apply this principle to the eye. The finger—eminently the seat of the sense of touch—sustains a relation to the body in general similar to that which the central part of the retina sustains to the retina in general. This central part is the immediate organ of distinct vision. The image, here formed in the axis of the eye, is that which gives the most distinct perception; and hence an accurate ocular examination of an object of sensible extent requires some rotation of the eyeball, by means of its muscles. Adaptation to distance in a given line also requires muscular action. Hence, if I direct my eye successively to the different parts of an object, my muscular sense informs me of the different degrees of motion requisite for the examination of different parts. Any two parts whose successive and accurate examination requires no muscular action, or the least appreciable muscular action, we consider contiguous. This is the elementary idea of contiguity, as perceived through the medium of vision. If, with the eye or finger, we trace an object from any given point of it, we consider its other points as more or less distant, according as their examination requires a greater or less extent of muscular action. Whether this extent is greater or less, we are informed by the muscular sense.

The perception of the true relative position of external objects is referable to the foregoing principles, which are common to sight and feeling. Let us make the application to vision. Suppose I am viewing a man who is standing erect on a horizontal plane—the image of the man's feet on my retina is certainly contiguous to the image of the plane—I therefore perceive the actual feet to be in contact with the actual plane. Of all parts of his image, that of his head is most remote from the image of the plane. I therefore necessarily judge that the actual head is the part of the body most remote from the actual plane. In short, I perceive that the man is erect and not inverted; in other words, that he stands on his feet, and not on his head.

The same principle is applicable if the body of the observer—instead of the earth—be considered as the standard of comparison. If, whilst I am conscious of standing erect, I include, in the same field of vision, another man's body and a part of my own, and if my image and his have a similar position, it follows, from the foregoing principles, that he must inevitably appear erect, although his image is reversed, with respect both to his body and mine.

We see then that there is not only a reason why objects appear erect, but why it is impossible that the eye could have been so constructed as to make them appear reversed. If the eye had consisted of an optical apparatus, which, like a camera lucida, should have changed the position ninety degrees, instead of one hundred and eighty, everything would have appeared precisely as it does at present; simply because the images of all bodies—our own included—would have had the same relative position that they now have.

That we have no direct perception of absolute position in space, is evident from every day's experience; for the globe we inhabit is at any

one moment reversed with respect to its position twelve hours previous, yet, from a comparison of objects on its surface, we perceive no change of position. So forcibly and habitually is this impressed upon our mind that thousands, who are convinced of the earth's rotation, find it difficult to realize, whilst the mass of mankind are with difficulty convinced of the fact; and no man would have discovered it, if no world but this had existed.

Whether we consider the perception of contiguity as resulting directly from the contiguity of the parts impressed, or mediately through the muscular sense, it is evident that this perception must be one of the earliest elements of our knowledge of position, and that there neither is, nor can be, any kind of eye so constituted as to make erect objects appear inverted, either with respect to the earth or an erect observer.

If we had made no reference to muscular action, the greater part of the foregoing reasoning would have been the same; and it is true, that, after a very short experience, we can judge of contiguity and angular distance from simultaneous impressions. The variable distinctness of these from different parts of the retina affords data. But as this distinctness diminishes equally in all directions from the centre, it affords no data for immediately determining in what direction we should move the eye, in order to obtain a distinct view. This leads us to the second division of our subject.

Let us now consider the question in its second sense. This is a kind of practical sense in which we may speak of knowing the position of objects, i. e., knowing in what direction to roll the eye, or move the hand in order to trace the object from top to bottom, or bottom to top, from right to left, or left to right, &c.

The particular modes in which different directions and different degrees of angular distance are estimated by muscular action, it is not essential here to consider. In the "Physiological explanation of the beauty of form,"* I have recognized in the vision of objects, the necessity of tracing them by means of the ocular muscles. This art, with its resulting knowledge and pleasure, is acquired only by experience. The young infant, though created with mental faculties for the estimation of form and magnitude, and for the enjoyment of beauty and grandeur, has no actual perception of either. In the investigation before us, we are chiefly concerned with the mode of estimating direction.

Suppose a child who has acquired the use of his hands, but who has been blind from his birth, to have the sense of sight given him by a surgical operation. At first he would be utterly unable to point towards an object, of whose situation he had no knowledge except that given by the eye. For example, suppose him looking at a star through a tube held near his eye by another individual. He would be unable on a first attempt, to direct his finger or arm toward the star, and would be as liable to move it in the opposite direction. If a higher and a lower star were visible through the same tube, and his finger were already directed toward one of them, he would be utterly unable to decide as to what kind of volition was necessary in order that his finger should move toward the other. He would be liable to the mistake of moving it up instead of down, to the right instead of the left, and in directions at all possible angles.

* Transactions of the Medical Society of the State of New York.

es with the required direction. It would be the same with the different parts of a single object. Suppose whilst he is pointing to the centre of the moon, he is required to point to its upper limb; he would in attempting it, be as liable to commence the motion in the direction of one radius of the disk as in another. In this sense of knowing its position, he has no knowledge of it at all; in this sense he neither sees it erect nor reversed. He can neither direct the hand nor the tube to any required part.

In directing the eye itself by the action of its muscles, his difficulty would in the first instance be as great, and subsequently much greater. Having no experience in this kind of motion, the direction of it would require a longer education. His condition as an observer, engaged in directing either the tube or the eye, would be infinitely more perplexing than that of an astronomer furnished with a telescope and required to change the direction of its axis from one star to another in the same field, having no information as to whether it gives erect or inverted images, and having no guide except the apparent positions as seen through the telescope. The first motion of the astronomer would be either in the proper direction, or exactly the reverse; the novice in vision would be able to err in an infinite number of directions. We are not to infer that his confusion would be in the least degree owing to the inversion of the image on the retina; were the image erect, the difficulty would be precisely the same. In both cases, experience would be required for the proper direction of the eye, and for the proper direction of the motions of the body. This experience we all acquire in infancy.

Our conclusions then are, first, that infants cannot see objects reversed; secondly, that the inversion of the image does at no period of life increase the difficulty of obtaining correct perceptions; thirdly, that any position of the image gives a correct perception of the relative position of objects with respect to each other, the earth and ourselves included; fourthly, that neither the erect nor any other position of the image could afford us any direct and immediate aid in tracing the object with the eye or the hand.

I will explain how a correct perception of position in the first sense—i. e., the position of objects with respect to that of other objects, and of our own bodies considered objectively, aids the acquisition of it in the second sense; i. e., in the sense of knowing what volition to make in order that our organs—as the hand or the eye—may move toward them.

I will illustrate it by the use of the telescope. When a young astronomer uses a kind of telescope to which he is unaccustomed, he may at first move it in the wrong direction, in attempting to bring a star nearer the centre of the field; but perceiving that the effect is to remove it farther from the centre, he learns to correct his mistake; and after repeated corrections, he acquires facility in directing the instrument.

Now, in what I have said of original ignorance as to the proper direction of the hand, I have not only confined it to first attempts, but supposed the view of the hand, as well as of other objects, to be cut off by a tube. Let us see how, under ordinary circumstances, our education in regard to a knowledge of position, in the second sense of the terms, is facilitated by that correctness of perception which I have proved necessarily to exist in relation to the first sense. I have said, that proximity and remoteness of two images, respectively give us perceptions of proximity and remoteness in the objects. Now suppose the view of the hand unobstructed. As the novice in vision moves his hand, its image on his

retina may either approach the image of the star or it may recede from it. If it approaches, then the real hand also approaches the direction of the real star; if the images separate, so do the directions of the objects. Thus, as he neither sees objects inverted, nor motions reversed, his visual impressions afford a correct guide in the education of his hand. In learning to direct his hand, he therefore has the aid of a principle similar to that which the astronomer employs in learning to direct his telescope.

The following recapitulation may afford a brief explanation of erect vision from an inverted image. When objects are in contact, their images on the retina are in contact; when the objects are more distant, their images are more distant. Hence these images give an approximately correct perception of the relative distance of objects and parts of objects; and a man standing on a horizontal plane, cannot appear to have his head above the plane and his feet in the air. Thus after a slight experience, the infant observer has some knowledge of angular distance, i. e., is conscious of the necessity of some volition in changing the objects of distinct vision. Yet of that specific character of the volition which is requisite in order that the motion may have the requisite direction, he may still be ignorant. In attempting to trace the object upwards, he might move the eye downwards, or to the right or left. He acquires by subsequent experience the art of directing the eye; and, in acquiring this art, he is aided by the correctness of his motions in regard to proximity and distance, and guided by the muscular sense.

The mind is not like an observer stationed behind the retina to compare the position of the image with that of the eye; as we neither see objects inverted nor motions reversed, and know, from the increasing distinctness, when the direction of the eye is approaching that of the object, we learn to regulate its motions. The experience essential for perfecting our knowledge of visible direction and position, is in the use of the muscles which change the position of the eye. These alone would suffice; those which move the head are auxiliary. This theory of the knowledge of direction and position differs from that which refers it exclusively to the education of touch. Touch is often auxiliary, but never essential. A knowledge of visible direction would be acquired by the infant, though its hands were immovably confined.

I shall conclude with an examination of "the law of visible direction" as applied to the explanation of erect vision. The reasonings and experiments here referred to are those found in Brewster's Optics. The law is this: the "visible direction" of any small object or point, is in a line drawn at right angles to the retina from the point of the retina on which the image is situated. Sir David Brewster,—a philosopher highly and justly respected for his numerous and valuable contributions to optical science, and regarded as the highest authority in matters pertaining to the eye,—affirms that "this law, deduced from direct experiment, removes at once every difficulty that besets the subject" of erect vision. I am not able to discover, in what he denominates "this important law of the physiology of vision" anything which, if true, has any bearing upon the theory of erect vision—anything which has the slightest tendency towards the solution of the real problem, nor in the experiments adduced in support of this law, any proof of its exact truth. The true theory of visible direction is intimately connected with the true theory of erect vision. A true

Explanation of the reason why we see all objects and all their parts in their actual directions, is an explanation of the reason why we see them in their actual position. This is what I have attempted. To show that an object is seen in a certain direction, is one thing; to show the reason why it is seen in that direction, is quite a different thing. Helmholtz must have seen this distinction when he admitted as a fact the law of visible direction,—on which Sir David Brewster insists as an explanation, and would “not undertake to explain” why the object is seen in this direction.* Should we state that any point is seen in the direction of a line drawn from its image on the retina to the common point of intersection of the axes of different pencils of light, this would be no explanation of visible direction nor of erect vision. The statement would have the same merits and demerits as this other celebrated law of visible direction, and it would be both true and superficial. It would be equally adapted to popular use. A single glance at a diagram of the eye and the refracted rays would produce general conviction. How could any one doubt that the two ends of the object must be found in the direction of the axes of the pencils of light which had emanated from them? Most persons would exclaim, “Surely it must be seen erect.” Yet, in recent and highly-respectable works, and on the authority of Sir David Brewster, the highest authority in such matters, the law of visible direction is preferred to as affording the most satisfactory explanation of erect vision.† It could be proved that the perpendiculars to the retina show the exact direction in which objects appear, still the reason why objects appear in a certain direction would be as far from being explained as before. Can any standard of direction give any knowledge of direction, unless we have the idea of the direction of the standard? We might as rationally pretend that we could obtain an exact idea of the length of objects by the application of a measuring rod of whose length we were totally ignorant, or guide a ship by the needle without a knowledge of its declination or variation.

Passing over the gratuitous assumption which seems to be implied, and to which I formerly alluded, viz., that we have an instinctive idea of the position of these perpendiculars—let us consider the facts relied on for the establishment of this theory. The first is this:—An object seen through a small segment of the pupil appears in the same direction as if seen through the whole. In other words, the lateral or peripheral portions of the pencil will, if concentrated on the same point of the retina as the central parts, give a perception of the same direction as the central parts, or the same as the whole pencil.

Now, the only legitimate inference from this undoubted fact, is, that the apparent direction of an object does not depend upon the direction in which the light arrives at the retina, but simply upon the situation of the point of the retina impressed.

All these supposed confirmations are but repetitions of the same general fact. If a more permanent impression is made on the retina, so as to produce a protracted vision of an object after its withdrawal, this ocular spectrum must of course, on any theory, obey the same law of apparent direction as the real object. Yet Sir David Brewster thinks it a con-

Vide Proceedings of the British Association for 1838, in which Dr. Brewster attributes the law to Dechales, Porterfield and Reid.

Elliotson's Physiology.

firmation of this law, that the ocular spectrum seen on shutting the eyes after viewing a black paper figure of a man held up in the direction of the sun, appeared erect or inverted according to the position of the object.

He also adduces the fact that "if we press the eyeball at any point where the retina is, we shall see the luminous impression which is produced, in a direction perpendicular to the point of pressure." On this he would remark, that when mechanical pressure on the eyeball produces the perception of light, the direction of the imaginary external luminous point from which the light appears to proceed, must appear to be the same as that from which light must have actually proceeded, in order to fall on the part of the retina mechanically pressed. Whether it be an actual luminous impression from without, or mechanical pressure generating illumination or light within, the law which I have stated applies; viz., the law of connexion between apparent direction and the locality of impression. The retina being so constituted as ordinarily to give no perception other than that of light; then if a pin-head excites it through the other coats, or a star through the humors, in either case there appears a luminous point, and this point, whether real or imaginary, must appear in the same direction, if the impressed point of the retina is in both cases the same.

The same law of locality of impression applies to another of Sir David Brewster's supposed confirmations of this law of visible direction by which he explains erect vision. The fact which he adduces is, that pressure on the eyeball changes the apparent direction of objects. His explanation is that such pressure "alters the spherical form of the surface of the retina," and consequently the direction of its perpendiculars which we regard as the lines of visible direction; and alters their planes of meeting which is regarded as the centre of visible direction.

In order to test this theory, I resorted to a simple experiment, which any one can easily repeat, and by which the theory is refuted. I placed a candle at a short distance before me, and look at a more distant object beyond it. Then, as the light falls on dissimilar parts of the two retinas, I see two flames. If I then press the right eyeball with the finger; the left flame, which is that seen by the right eye, changes its apparent place. Now the problem is to determine whether this change of apparent place is attributable to a change in the location of the image on the retina, or to a change in the form of the eyeball. In one respect, the problem is a little complicated, inasmuch as a change in the form of the retina would generally be attended by some change in the locality of the part impressed, as well as by a change in the direction of its perpendicular; so that even were the axis of vision unchanged by the pressure, Sir David's explanation would not be confirmed by the effect of pressure in changing the apparent direction. The effect might still be—and so far as depends on change of form undoubtedly is—owing to change of locality in the image. But in order to remove all ambiguity arising from this source, and to render it evident that the change of direction in the object produced by pressure is not chiefly attributable to a change of form of the retina, I modify the foregoing experiment in the following manner. Instead of forcibly pressing on the eyeball, I rub the finger gently over it, so as to rotate the eyeball without sensibly changing its form. The finger being gently pressed on either eyelid, is drawn over the eyeball parallel to its surface. The consequence is that *the change in the apparent position of the flame is much greater than that which results from the most violent pressure.* Such a result is wholly inexplicable by Sir David's

Lawster's hypothesis of change of figure; but is precisely what might be expected if apparent direction is changed by moving the image on the retina, and if pressure on the eyeball produces that change of locality in the image. The hypothetical virtues of radii, perpendiculars, and the centre of visible direction," find no support in this experiment.

The experiment may be varied in the following manner, so as to disagree with the two images of the candle, and yet lead to the same conclusion. Shut one eye, and rotate the open eye with the finger in the manner above described. Then all objects will appear to move in the direction opposite to that in which the eye is rolled; in the same manner and for the same reason, that the supernumerary flame did in the preceding experiment. For example, if the right eye is rolled to the left, the panorama of the field of vision moves to the right, for the images are formed farther to the left, like those of objects situated farther to the right. A similar, though less effect is produced by strong pressure. I find that pressure towards the left produces apparent motion towards the right, and vice versâ. This confirms the conclusion, that the effect of pressure depends upon the rotation it occasions. To establish this still more conclusively, I direct the pressure more and more backwards, and find the effect diminished; and when by pressing simultaneously over different points of the eyeball, I produce a resultant force almost directly backwards in the direction of the axis, I find the apparent motion of objects reduced nearly to zero. This is precisely what should take place, if the illusion results from a change in the location of the image, but is entirely different from what should take place if it resulted from a temporary oblateness of the eyeball, and a consequent change in the direction of the radii.

It is hardly necessary to add, that every change in the location of the image is not attended with a perception of motion of the object. Whenever this motion of the image is occasioned by a voluntary motion of the eye, the head, or the whole body, we are conscious of the motion of the eye or of our body, and attribute the change of sensation to its true cause: in the ordinary rotation of the eye, objects which are with respect to us actually stationary, appear so. But when a change in the location of the image results from motions of the eye not produced by the muscles which ordinarily produce it—as for example when the eye is rotated by the finger—we attribute the motion to the object. With a rotation—as in the experiment before described—the object appears to move; yet according to the law of visible direction, there should be no apparent motion. The law is thus transgressed by nature, and is therefore no law. The concession before made in regard to its approximate truth, applied only to ordinary vision. If the eyeball is, by means of the finger, rotated to the left, then the perpendicular drawn from the image on the retina is not directed to the apparent place of the object, but passes it on the left side. Experiment appears to me to overturn the "law of visible direction," considered as a statement of the direction in which objects actually and in all cases appear. The perpendiculars—however nearly coincident with the axes of the pencils—have no inherent power, as perpendiculars, to control our judgment in regard to direction. But if this law were true in point of fact, it would still afford no explanation of apparent direction or erect vision.

