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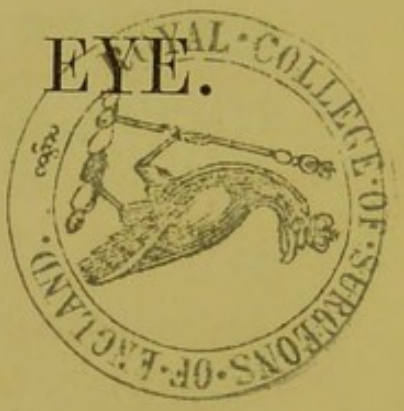
ON THE MEANS EMPLOYED

FOR

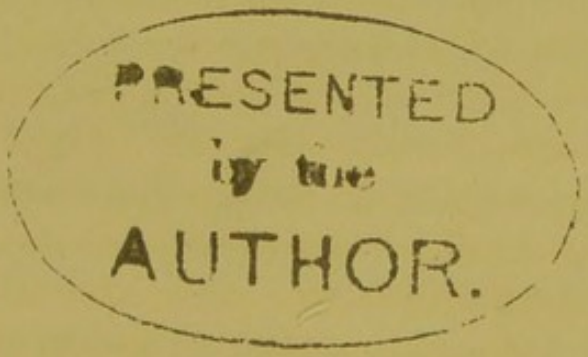
CORRECTING THE INVERTED IMAGE

ON THE

RETINA OF THE EYE.



By JOSEPH SWAN.



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PREFACE.

In the explanation entered upon in this paper, the powers both of the instinct and intellect have been adverted to. In the process described for correcting the inverted image on the retina of the eye, both the ready instinctive power and the more deliberate one of the intellect, either by acting together or separately, form principal features in its performance in man and animals; the first existing as the leading agent in all animals, whilst the powers of the last gradually wane until the glimpse of intelligence becomes more conformable to the functions of the organs of the body than for directing a large sphere of action through the extent of its own influence. It therefore becomes necessary to enter into a somewhat detailed notice of their respective peculiarities.

As all the functions of the body are performed so readily and effectually by natural provisions, it may

appear that an exciting power on the one hand, and a perceptive structure on the other, under the guidance of the intellect or instinct, are sufficient for their perfection. But there must be particular forms of the centres of the brain and a corresponding disposition of their tracts, through which the varied powers of the intellect or the more predetermined ones of the instinct can be manifested, and the organs of the body combined and controlled, therefore a precise knowledge of the structures is necessary for comprehending their mode of agency.

When the impulse has been communicated to any organ of sense, it must pass directly towards the sensory; this process takes place in all creatures, and constitutes the first stage or the instinctive act. When the impulse has been noticed or accepted by the sensory, it becomes the second stage or the intellectual act. In the lowest creatures the impulse serves for the momentary uses required for their preservation, but as the brain becomes larger it is more and more appreciated until it reaches the highest state allowed by the convolutions which minister to the intellect.

Because the inverted image on the retina is so readily and surely corrected, it may be assumed that no determinate structure is engaged in the process,

but the same excuse might be urged in relation to the particular functions of the separate organs of every animal. The will acts through special associations of fibres correctly placed for the purpose, but the person knows nothing respecting such an arrangement, he merely wills to place his limbs in the desired direction. Nevertheless, an especial structure and disposition of all the parts concerned is absolutely necessary in the production of every motion. The several senses, are varied by the structure and shapes of their respective organs and modelled on the same plan in man and animals, and the intellect in all of them is bounded by the extent and configuration of particular parts of the brain. When all the variations of shape and size have been duly compared together, the chief differences between the lowest and most exalted perceptions of the intellect in animals must be attributed to the additional parts of the brain subservient to it. But there may be further variations of the powers of the intellect or instinct by special arrangements in certain localities of the brain or by special tracts proceeding from it for producing predetermined actions, and a capacity for carrying out the appropriate contrivances through changes in the organs of

numerous animals. Many of such provisions are ready at birth, and others come gradually into force along with the growth of the corresponding organs which act with them.

Although the instinct through its perceptive* vital forces is considered as the measure of the intellect in all animals, and of the capacity of the organs for producing processes, which cannot be exceeded, a similar spontaneous influence must equally govern many of the organs of the human body. Its definite power must be obeyed according to the nature and peculiar structure of the various organs and

* "But they ought carefully to have searched after the difference betwixt perception and sense, not only in comparing sensible with insensible things, in the entire bodies thereof, as those of plants and animals, but also to have observed in the sensible body itself, what should be the cause that so many actions are performed without any sense at all. Why the aliments are digested and discharged, the humours and juices carried up and down in the body, why the heart and pulse beat, why the viscera act as so many work-shops, and each performs its respective office, yet all this and much more be done without sense. But men have not yet sufficiently found of what nature the action of sense is; and what kind of body, what continuance, what repetitions of the impressions are required to cause pain or pleasure. Lastly, they seem totally ignorant of the difference between simple perception and sense, and how the perception may be caused without sense. Nor is this a controversy about words, but a matter of great importance. Wherefore let this doctrine be better examined as a thing of capital and very extensive use."—*Lord Bacon* "*De Augmentis Scientiarum*," vol. i,, section 10.

of the centres or tracts. The parts most decidedly governed by the instinct, both in man and numerous animals, are the viscera of the thorax and abdomen, and on some occasions those contained in the pelvis. Probably the next in order are the contrivances for the correction of the inverted image, and those for the lateral motions of the muscles secured by the oblique crossing. In only a somewhat less degree the organs of the senses, on account of their precise construction, cannot be much raised above the circumscribed forms; the larger voluntary muscles have limited powers, but the finer motions of the muscles which act more in connection with intellectual processes, may be much more extensively varied. The several parts of the brain, according to the required centres for the nerves, and those destined more particularly for acting with them, however large, serve chiefly for the confined measures of the intellect and will. Some of the organs of the body come into use immediately after birth both in man and animals, and others more or less quickly; any varied direction by the intellect and will depends very much on the earlier or later maturity of the parts of the brain subservient to such faculties. As the brain is the most protracted in coming

to perfection in man, it forms a striking difference eventually through its own development and that of the powers of the mind, whilst the intellect of animals remains nearly stationary after the maturity of the brain has been accomplished. Very early the powers of the centres of the brain in man, belonging to the nerves of the organs of the senses, remain without much further change, but rather later those of the nerves of the larger muscles. The arrangements for predetermined actions, as the crossing for securing lateral motions and the arched fibres for correcting the upright inversion of the image, continue without much further change, but perform perfect functions from birth, or soon after, almost without the slightest attention, and yet these several processes act independently of the intellect and will never fail of being completed with the utmost quickness and precision, through a complex and extensive series of fibres, so long as the mechanism of the organs is sound. It must, therefore, be concluded that the correction of the inverted image, until it reaches the thalamus, approaches nearest to an instinctive act, as it cannot be prevented from taking place when the eyes are open; the power of adjustment of the images by the muscles also

borders on a reflex or instinctive act, except when the muscles in accordance with the intellect are voluntarily engaged for directing the eyes to particular objects.

Some processes are the ready acts of the instinct, as those of the senses; but others depend on the intellect after it has been instructed through impressions made on it by the senses. The intellect alone is not, however, capable of directing the functions of certain organs of the animal without such assistance for its guidance, especially in those creatures born perfect, and which have to provide for their own sustenance without delay.

With respect to some essential acquirements even the mind remains ignorant and powerless without the help of the organs of the senses; it cannot fashion the actions of the muscles for particular motions, especially for the production of writing or speech, until it has been instructed through them. However different the form and sound of words may be, the intellect, without the perfection of the organ of hearing, can never comprehend their sounds for fashioning the motions of the lips and tongue for speaking.

The subject of this paper presented itself during

an extended investigation of the functions of the nervous system, and more particularly whilst the sensitive division was under consideration. As the existence of any decided crossing in the sensitive centres and nerves is equivocal, it became necessary to determine whether the crossing of the optic nerves is part of a principle relating to sensitive nerves, or whether it is attributable to the accordance and compensation required by changes for carrying out the physical laws of optics. As far as the correction of the inverted image is concerned the inquiry is both curious and interesting, but it becomes of much more general importance by the consideration of the very large proportion of the sensitive centres and nerves thereby left undetermined; for if the optic nerves cross according to physical laws, this occurrence need not be esteemed as part of the necessary economy in relation to the remaining extensive section comprehending the special senses and common sensation. Such a determination would set free all the other sensitive functions, and allow them to be carried out under a law of their own.

In the following pages the plan for correcting both the upright and lateral inversion of the image

on the retina has been considered, and as the crossing of the optic nerves relates to the lateral motion of the image, the question has been entertained how far it is resembled by that of the motive tracts before they enter the spinal cord for the production of lateral compensations, and by that of the divisions of the par vagum before their final distribution on the stomach and other viscera.

6, Tavistock Square,
October, 1865.

ON THE MEANS EMPLOYED

FOR

CORRECTING THE INVERTED IMAGE ON THE RETINA OF THE EYE.

The eye is constructed of parts contributing to the completion and maintenance of the several optical contrivances for the regulation of the admitted light. The retina is especially fitted for the acceptance of light, as the natural and only stimulus of the optic nerve and the parts of the brain contributing to its origin; but it is seldom concerned except with the modifications of light reflected from objects, and refracted by the crystalline lens and humours, by which it receives images of every varied form, but in an inverted position. The removal of the objects at once makes it free and ready for noticing succeeding objects without any other process.

In whatever state the image of any object enters the eye, it is delineated on the retina in a position the reverse of that accepted by the mind. Whatever may be the natural form of the external object it is reversed according to the laws of optics on

reaching the retina, so that the superior margin is placed below, whilst the inferior becomes uppermost; the right side is depicted to the left, and the left to the right. The image of an object placed upside down becomes erect on the retina, but on reaching the brain is restored to its exterior reversed position. Although the eye, by the deflecting power of the lens and humours, in reality reverses the position of exterior objects, they are only in progression to be restored to their original characters by the arrangements of the nerves and tracts through which they are to be conducted by their centres and the convolutions of the brain to the sensory.

Although the remarkable semicircular position of the optic tract in its descent from the posterior part of the thalamus over the crus of the brain to the optic commissure has been described by anatomists, the uses of the disposition of the fibres have been very seldom adverted to.* Their form and arrangement are evidently adapted for allowing the convenient position of the eye at the frontal and lateral aspect of the head and face, and for being adapted to the various parts with which it is intended to co-operate for completing vision. If the fibres of the optic tract had been carried in a directly straight line from the posterior part of the thalamus, they would have terminated near the back of the head. For allowing the eye, therefore, to be placed in its

* After this paper had been corrected for the press an instance was found in "The Nervous System," by Alexander Walker, p. 187.

present convenient situation, it would have been impossible for any other mode to have been adopted than that of bending the fibres of the optic tract, and thus at the same time forming a plan in conjunction with the crossing in the optic commissure for the correction of the inverted image on the retina in its course to the thalamus and convolutions of the brain. It may be a question whether this is the only use of the arched fibres of the optic tract, and those of the thalamus, or whether their divergence in their course, and in the thalamus, may not allow some expansive power, relating to the determination of the magnitude of the objects during the ascent of the image to the brain.

In the correction of the inverted image on the retina of the eye in its ascent to the brain, two different means are employed: the one in relation to the upright position of the image; the other in relation to the lateral. The upright position is rectified by the oblique and arched fibres of the thalamus and optic tract; the lateral position is corrected by the altered arrangement of some of the fibres crossing in the optic commissure.

The arched fibres proceeding from the thalamus and optic tract and nerve form the full half of a circle, and in bringing the fibres straight, the optic nerve and tract have their downward position reversed; for if the eyes are then carried backwards, accordingly as they are delineated in the diagrams, the retina will be brought to a line with the longi-

tudinal fibres of the surface of the thalamus. If in a diagram, the eye, the optic nerve, and tract of the opposite side are separated, so as to be capable of passing obliquely through the crossing in the optic commissure, and then carried backwards, and continued in a line with the surface of the thalamus, the inverted image stands corrected with respect both to its upright and lateral positions, but without the crossing in the optic commissure, its lateral aspect continues to be reversed. What the straightening of the arched fibres allows to be done mechanically in correcting the downward position of the inverted image and the crossing in the optic commissure in correcting the lateral position, the vital perceptive force accomplishes through the same tracts of fibres in their natural arched and crossing condition.

In the ascent of the image from the retina by the optic nerve, the outermost portion or letter delineated on it is conveyed upwards through the outermost fibre of the thalamus to stand first in the true visual tract next its convolution, then the second is conveyed through the next fibre in the same way, and so on to the end. In a similar manner from the innermost portion of the retina the letters are conveyed by the innermost fibres of the thalamus. The same arrangement is required in both eyes with respect to their corresponding sides of the head. Each letter must be traced from either eye obliquely through the optic commissure to the opposite optic tract and thalamus, for if it be taken directly

through the same side of the optic commissure to include the optic tract and thalamus also of the same side, it will be found that the upright position is corrected, but the image of the letter or word remains reversed laterally.

There may be one image accepted by one or both eyes at the same instant, or it may be a picture comprehending several objects. If both eyes are used there must be a consent between the muscles and retina of both, that the image may be perfectly formed for its acceptance by the sensory. When attention is to be given to somewhat minute objects, as in reading, it will appear on examination of the diagrams, how the whole image, or how one half of it may enter one eye, and the remainder the other, and how, after the image on each side has been corrected, it reaches the true visual tracts, and from them is extended to neighbouring convolutions on each side of the brain belonging to the median or intellectual region to be combined through the great commissure, and thus have its mental qualities accepted by the sensory, either alone or in combination with other words. The same process is required for appreciating the image of any other objects.

When a moderate view is contemplated, the muscles move the eyes to the furthest point on each side, but when it is to be much enlarged, the muscles of the head co-operate with those of the eyes. According to the degree of attention and time allowed for the completion of the process,

the picture becomes almost entirely evanescent, or from careful observation each particular object may have become noticed by the intellect, and the more prominent or striking ones imprinted on the mind. But almost without any change of the position of the eyes or head a rapid succession of images may be cursorily noticed, as in riding, or from a carriage in swift motion, and leave a general pleasing or a very confused impression on the mind according to the distance and particular attention bestowed on them. The images passing before the eyes during quick motion must have their inverted position corrected. Yet, notwithstanding the acknowledged celerity of communication between the nerves and the intellect as a general rule, it may seem that some further and particular convention between the retina and its centres in the brain, are required for completing the acceptance of the admitted images. The course through the arched and crossing fibres may seem circuitous, but it cannot delay the necessary quickness of communication. It may also appear remarkable that the passing images can be so promptly effaced for making the retina clear for accepting succeeding ones with so much fidelity, but as the retina always becomes free as soon as the object is removed, no interruption or confusion can take place. The medium through which the impulses are received is so different from that offered by the organs of the other senses, that the impressions do not linger on the retina as they do on the nerves of

the other senses. An uneasy feeling from the excess of light may continue, but not the images usually presented in ordinary vision.

When the number and complexity of the images which have in this manner passed so quickly before the eyes are considered in their inverted condition, it can only be concluded that if they were not at once corrected by an unerring and ready plan like that adapted for conducting them forwards through the arched fibres of the thalamus and optic tract and the crossing in the optic commissure, independently of any voluntary or other intellectual interference, after the image has quitted the retina, such regular pictures could not be so freely presented, and fresh ones so instantly substituted for them.

The optic nerve and retina allow the images perfected and combined by the two eyes to be noticed as one picture. The communications between the retina of each eye and the sensory by means of the great commissure, may be only employed when the intellect is attentive and participates in the process. The thalamus and the convolution of the true visual tract may be sufficient for the more physical optical powers, the two eyes being combined very much through the optic and other commissures, and mutually adapted through the association of the retina with the muscles when the mind is not attentive, the muscles then acting with and according to the entering image, and not through any intervention of the will.

For present sight the eye seems to require no preparation, but when open is always ready and can sufficiently implicate the actions of the muscles for assisting in the position of the image without the intervention of the will. The sensorial power is ever present in the retina, and when the image has ascended through the thalamus, it is received by the convolutions of the brain in co-operation with the intellect. When it excites the motions of the limbs, as for writing, or the tongue and lips for speech, it is not conveyed forwards to the motive nerves and muscles by any communications between the sensitive and motive centres, but becomes a new departure from the intellect by which it is re-modelled, and then can be reproduced as the same image, or be more or less altered in the process of transmission.

In animals there is a varying modification of the process for conducting the images from the retina to the brain. In mammalia there is a similar thalamus, and similar optic tracts supported in an arched form by the crus of the brain. In the other three classes the optic nerve, by proceeding from more or less rounded optic lobes, and passing with some obliquity to the eye, may correct any aberration in the ascent of the image in conformity with the lateral course to the opposite eye, either with or without the combination which takes place in the optic commissure. In many of the higher kinds of mammalia the convolutions more or less resemble those of the human

brain, and the intellect may, therefore, appreciate the images from the two eyes in a similar manner, but in an inferior degree. In lower kinds of mammalia the median or intellectual convolutions diminish, and in a corresponding degree the great commissure becomes contracted to a mere line. The adaptation of sight then begins to depend much more entirely on the subordinate parts which assist the visual process in the highest animals, and in man for ordinary vision, when the intellect is not attentive. The connection of the optic nerves with the brain through the optic lobes, the mammillary bodies and the epithelium of the ventricles forms the only combination in osseous fishes, as the optic commissure has ceased to appear, but the rounded optic lobes and a similar oblique course of the optic tracts are still capable of countervailing any deviation of the images.

In mammalia the optic nerve, optic tract, and thalamus are capable of allowing the same optical powers as in man, and the true visual tract is in proportion; it is clear, therefore, that the several parts co-operate in producing as efficient an act of vision, but when the image has reached the sensory, the less extent of convolutions subservient to the intellect makes certain differences in the deductions capable of being drawn from the same images as are received by the human eye. There are gradations of the optical powers of the eye in the descending scale of animals, but probably not so decidedly infe-

rior as in the parts of the brain the centres of the optic nerve are connected with, for a co-operation with the intellect. The small connection with the brain, however, permits the animals to comprehend the nature of such objects as their diminished intellect is capable of appreciating for their appointed uses.

The less extent of the great commissure and convolutions is not the only difference between the appreciation of the images by man and the highest animals. Although the impulses on reaching the convolutions in some of the higher species of mammalia are combined by the great commissure, it is only in man that any information relating to the mental qualities can take place. The mind in man has the additional power of separating the impressions into mental and corporeal, or accepting mental representations through words constituting language. Mental qualities may also be accepted through any of the other senses. In the conveyance there is no difference whether they contain mental or physical qualities; nevertheless, the mind attracts its own kind of information and over such qualities the intellect of animals has only a slight approach to the same power. In animals the inverted image is corrected, and the eyes are in every respect perfect, but they have not this superior qualification; it is clear, therefore, that the structure of the optic nerve, and tract, and centres in the brain have no other properties derived from their specific form than

those of framing and correcting the inverted image by an optical and vital process, the intellectual part being left to the convolutions and instinct in animals and to the convolutions and mind in man.

To very numerous animals the perception of light is pleasing, but to others a limited degree of it, approaching twilight, is more grateful, and serves for exercise and the acquisition of food. To many birds the influence of light seems to be nearly as powerful an agent as the intellect and will, for it keeps them in activity through the longest as well as through the shortest days. Animals seeing by twilight must have the images reversed and corrected in the same manner as those enjoying the participation of the more brilliant degrees of light to be enabled to see as distinctly as is necessary. The tapetum in some instances, and the more irritable state of the retina, the size of the eye, and form of the pupil in others, compensate in some measure for the diminished light; the greater acuteness of their other senses also lends its assistance. The powerful agency of light secures its passage through the optic tracts, it harmonises more closely with the intellect than the leading exciting influence of any other sense, and in animals more especially, tends to the enlargement of their knowledge of such natural or artificial objects as they can through its power become acquainted with.

Many young animals almost immediately after birth can exercise their limbs freely in concert with their eyes, and their powers of co-operation have

been predetermined and provided for in the early development of the brain, and especially of the centres and nerves connected with the completion of the organs, otherwise their eyes and limbs could not have been brought so speedily into requisition for accomplishing previously untried and dangerous exercises. Many young animals are carefully tended after birth, but some are left to themselves; and unless everything is made perfect in the brain and nervous system, likewise in the organs of the senses, the muscles and the nutritive organs, so that they may be directed to their food instinctively, they would perish from want.

Many learned men have tried to account for the correction of the inverted image on the retina by ingenious speculations, and others by believing that the intellect by its own discernment is able to effect it without the intervention of any mechanical contrivances for the purpose. It has also been a prevailing opinion that it can be corrected by previous information acquired through the earlier activity of other organs. In the human species and some animals, which have everything provided for their safety and growth, such an intervention may be admitted in a slight degree, but as other animals are born perfect and able to use their organs without the slightest delay, there is no excuse for presuming that they have acted from any previous experience.

All the knowledge possessed by animals or even by man has been received through the organs of

the senses, some of it by one alone, but the greater part of it by their mutual assistance. For this purpose, and for such a manner of acquiring instruction, there need not be communications between the several organs, their centres or nerves, for the impulses of each are taken to and completed by the intellect, which determines and appreciates their several functions, especially after they have been adopted by repeated trials by the intellect. The senses can then be substituted for each other for selecting or avoiding the objects or matters which have been presented to them. After a time the senses are less exercised and the intellect is occupied in their stead, which can then act by its acquired knowledge, without perpetually renewed impulses. Even in animals this experience to a limited extent is made use of, as there is a memory of objects and the avoidance or desire of them according to their previous uses. All this can be done when there has been time for learning the nature of the various objects which have been presented to the several organs, but still experience cannot be urged as the expositor or cause of such required proceedings in new-born creatures. There must not only be a perfection of the several organs, and their nerves and centres, but to a certain extent of the brain itself, for allowing the instinct to command, and the muscles to obey in completing the required actions.

"We might indeed call in experience to our assistance, and habitually correct the errors of one sense

by a comparison with the perceptions of another. But it appears that some philosophers have been too hasty in supposing that the use of all our senses is derived from experience alone, and in disbelieving the existence of instinct independent of it. Without any other authority than that of their own imaginations, they have denied the observations recorded by Galen on the instincts of a kid, which is sufficiently credible to counterbalance much more than bare assertion. The instant after its birth, accompanied by the loss of its mother, the little animal ran to some green vegetables, and having first smelt them, chewed and swallowed them. The kid could have been taught by no experience to be tempted by the sight, to act with the proper muscles of locomotion, to go near and smell, and to be induced by the smell to masticate, and by the taste to swallow and digest its food, had it not been provided with some fundamental instinct by the same intelligence which so calculated the adjustment of the eye that the lens should be able to produce a perfect image of every object, and that the retina should be of that precise form which is exactly suited to the reception of the image to be depicted on it."*

The lateral correction of the inverted image does not form the entire use of the crossing through the optic commissure, but its correspondence with the motive ocular nerves originating from the same

* Dr. Young's "Lectures on Natural Philosophy," vol. i. p. 449.

side of the brain, is also favourable for promoting the almost perpetual sympathy between the muscles of the eye and the retina for producing the required motions harmoniously with the entering image. The branches of the third nerve are alone required for the attollent and depressor muscles, which must act in harmony whenever they assist in preparing the image for its conveyance through the arched fibres. For assisting the crossing tract in correcting the image laterally a branch of the third nerve is used for the adductor muscle, but it is opposed by the sixth for the abductor muscle, and has to co-operate more or less with one or both oblique muscles. The muscles adjust the images on the retina, but not further towards the brain, their scope of action being inadequate for so large a correction as is effected in the circuit of the arched fibres or those crossing laterally.

The nerves of the ocular muscles proceed straight from their origins, and so far they differ from the arched course of the optic tract. Although there are separate nerves for some opposing motions, they are governed very much by the sensorial or sympathetic powers of the retina. The voluntary interference is brought more sparingly into use except for the particular observance of objects by the intellect. The third and sixth nerves have no direct connection with the retina, neither has the iris; their combinations in man and some of the higher animals are therefore effected by a special convolution placed

next to and often intimately connected with that of the true visual tract, and then extended through its own tract to the origin of the third nerve, to which it imparts high sensorial powers and enables it to sympathise directly with the retina, the lenticular ganglion, and iris; through another similar convolution the sixth nerve also derives some degree of the same power. The retina and interior of the eye are associated by branches of the fifth nerve supplying the parts of the orbit anteriorly, and the branch of the fifth entering the lenticular ganglion. The iris is combined with the retina and muscles through the sensorial influence super-added to the third and sixth nerves by which the entering image is adjusted before its ascent to the brain.

As the crossing in the optic commissure restores the lateral inversion of the image, it seemed not improbable that the crossing of the motive tracts at the crus of the brain and oblong medulla might confer similar lateral properties on the motive cerebral and spinal nerves. The general functions of the body and limbs are principally effected in obedience to the will, for all the larger and more powerful motions as well as for many of the smaller ones. The motive and sensitive nerves are intimately connected together for the co-operation of the muscles and skin, as in the use of the limbs for voluntary exercise, and not for reflex motions in any

degree equal to that promoted by the retina in the adjustment of the image for vision.

The retina and the motive tracts for the muscles of the limbs would correspond as to their connection with the convolutions of the brain; if the arched fibres of the optic tract and thalamus were made straight. Inasmuch, therefore, as both have crossing arrangements, the optic tracts at their commissure and the motive tracts of the muscles of the body at the oblong medulla before they enter the spinal cord, a sufficient resemblance exists for determining that both are formed on the same principle for modifying the functions of their respective nerves. The direct fibres of the tracts proceeding from the motive centres in the brain already correspond with the straightened arched fibres proceeding from the retina, and with those of the ocular muscles. The crossing therefore of the tracts of the oblong medulla, which promote the lateral direction of the adductors and abductors of the body and limbs are in a high degree analogous with the crossing in the optic commissure for securing the lateral direction of the image.

The several layers of the motive region of the brain are definitely marked out for the flexors and extensors, but not for the adductors and abductors, the direction of these is therefore to be secured by the crossing in the oblong medulla. Very few of the motions of the body consist of pure flexion and extension, so that a large crossing of the tracts of

all the motive centres appears necessary, by which not only decided lateral motions are secured, but also intermediate or circular ones by the co-operation of the flexor and extensor muscles with those of adduction and abduction. In this respect the motions of the body and limbs are analogous with those of the ocular muscles and the functions of the optic nerve, as the retina must partake both of the upright, lateral, and intermediate or circular adaptations to the images. If the crossing of the optic nerves, or the motive tracts for the body and limbs does not confer any sensorial property, it allows an altered direction of the parts it engages by adding a more decided impulse to lateral activity than could be effected by any other means, equally simple for securing the co-operation of the flexor or extensor muscles.

Inasmuch as the motive nerves proceeding from the spinal cord have a considerable influence over lateral or oblique motions, the several motive cerebral nerves may be included in the same class. The third, with the exception of the branches for the attollent and depressor muscles, the fourth and sixth, the smaller portion of the fifth, and the hard portion of the seventh, and the ninth supply muscles having one kind of motion like the flexors or extensors, but which require to have a lateral tendency, or such as enables them to co-operate in circular or other compound actions with their fellows on the opposite side. The muscles supplied by the small portion of the fifth, the hard portion of the seventh, and the

ninth have only single motive acts to perform on the same side like the ordinary flexors, the principal contervailing power consists in the corresponding muscles of the opposite side, and not of two kinds for flexion and extension on the same side as in the trunk of the body and particularly in the limbs.

The retina can have its inverted images corrected by the arched fibres and the lateral crossing instantaneously, whilst the motive impulses can be as quickly corrected through the crossing fibres when their own tracts are actuated by the will. Both these vital actions or motions emanate from parts having apparently dissimilar properties and pass in contrary directions, and in some respects the results, although different inasmuch as they excite organs concerned for such different purposes, in their intrinsic actions appear similar as far as they belong to nervous matter having an analogous crossing arrangement, but the motions for correcting the image on the retina approach nearer to those concerned in automatic processes and are so far peculiar.

The image on the retina has as distinct a form as that of words, and can be conducted to the intellect and from thence to the muscles for reproducing a resemblance of the same by writing. The centres of the optic nerve therefore seem to approach in such respects both the quality of the motive centres and that of the convolutions subservient to the intellect, for images or words to have become capable of being

accepted from the retina, and then transferred through the motive centres to be written. It must, consequently, be presumed that the motive centres and muscles require similar but modified properties to those of the retina and its centres for allowing the production of such marked resemblances. The centres for the reception of sensitive impulses are composed of similar matter to those of the motive, but modified by its arrangement, such impulses proceed to the intellect for recognition and the motive pass from it for the excitement of the muscles. The image received as perfect by the intellect has proceeded from the material stimulus of light or sound, but its reconveyance from the mind through the immaterial will. The process is not always conducted in the same precise order, as the impulses from the senses can be retained and after sufficient experience reproduced in contrary ways, as by speaking instead of copying, through the hand and eyes, or by writing words heard by the ears, instead of speaking them. The process cannot, therefore, be completed by a communication between the sensitive centres which convey the impulses, and the motive which reproduce them, but must be attributed to the acquired powers by the instruction of the mind. For the correction of the inverted image there is not the same probability of change, as it does not depend on the versatile powers of the mind.

In the progress of the image to be transferred, the first impulse is made on the organ of sense having

an appropriate form and quality of structure for allowing peculiar mechanical impressions on the nerve and its centre, it is from thence conveyed to the convolutions and intellect, and this forms the first complete stage. The continuation of the impulse or image reconveyed from the intellect through the will by the motive tracts and nerves to the muscles, forms the second complete stage. Whatever, therefore, after the completion of the first stage takes place as the continuation of the sensitive impulse, is a new act of the intellect through the will by which the muscles are engaged for reproducing the mechanical form of the image, and constitutes the second stage. As the intellect does not originally contain a knowledge of the image or sound, or of the process by which they are reproduced, although all the parts are prepared for their accomplishment, it seems to be the commencement of an experiment, and at length becomes perfected through the gradual exercise of the muscles, which are enabled to modify the direction of their actions in accordance with the pattern previously received from the organ of sense. After sufficient experience, but in some instances almost intuitively, the eye no sooner sees the object than the intellect can command the muscles to convey it to paper. Impressions remain more or less permanently on the intellect of animals; some birds, however, can transfer the words at any time through the glottis, but cannot, like the mind, change them for other purposes.

Persistent acts, which cannot be changed, are effected by the addition of the crossing, so that the motive tracts of the oblong medulla may cause the motions to assume a lateral tendency, without the interference of the will through additional complex motive centres. The lateral correction of the inverted image approaches this persistent condition; and, therefore, it takes place in its passage instinctively, and not when it has reached the capricious intellect. The correction of the inverted image corresponds with the provision of such properties as are required for the ready uses of the instinct in a much greater degree than with the sensorial part of vision, depending on the convolutions of the brain for its completion by the intellect.

If the same complex acts were required for the acceptance of the image by the retina, and for the correction of the inversion as are demanded by the intellect for its appreciation, and especially for its conveyance by the muscles to the hand for writing, the sight might eventually be perfectly accomplished, as well as the required motions of the voluntary muscles. But the predetermined perfection of sight and the more common motions of the muscles, would have had their intended uses too much protracted for serving their early necessities, and especially of such animals as require to have their senses and capacity for efficient motion perfect at birth; and, therefore, some particular centres in the brain have been prepared, and such other substitutes

as by crossing, for enabling the dawning intellect to act by supplying immediately certain necessities for self-preservation. The required organs have also been prepared for carrying out the predetermined processes.

There has been much difficulty in understanding the uses of each particular disposition of the numerous divisions of the trunks of the par vagum. The superior laryngeal and recurrent nerves and the pulmonary plexuses are directed chiefly to the corresponding sides of their respective organs, but below the bifurcation of the trachea, the remaining large portions destined for the œsophagus, stomach, and other parts of the chylo-poietic viscera, more or less decussate each other before their final distribution. The decussation of the two trunks of the par vagum on the œsophagus, is very evident in the human subject, and modified in its arrangements in animals, probably to suit their particular functions. The involuntary and irritable character of the par vagum is favourable for promoting automatic actions, but without some predetermined mode of agency is not sufficient for directing the motions of the muscular coat for producing the required peristaltic action.

As the lateral inversion of the image could be corrected, and the lateral motion of the ordinary voluntary muscles secured by crossing, it seemed

not improbable that lateral involuntary motions might also be promoted by similar means. It appeared during this inquiry that the interchanges of the trunks of the par vagum from right to left and from left to right, may be formed for giving a lateral inclination to the involuntary motion of the stomach, and tend to its continuation as the peristaltic action to the intestines, in some measure through its communications with the sympathetic nerve. With the exception of the optic nerve and those of the heart, it is the only instance in which there is a similar resemblance of decussation in the nerves themselves from the opposite sides of the brain. This change in the arrangement of the two trunks of the par vagum does not take place until actions of a particular kind are required for producing a tendency to lateral motion from the stomach throughout the intestinal canal.

The uses of many of the more ordinary centres of the brain may to some extent be made plain, also the more direct combinations between the two hemispheres. Very unsettled notions, however, exist respecting the decussations or oblique crossings of the fibres and tracts. If all the parts of the brain crossed, there would be an apparent uniformity for producing a single source of power, but very probably it would not be more efficient for ministering to the various offices of the nervous system in con-

nection with the body, than single direct or oblique fibres. There is a beautiful decussation of the fibres in some crystals. "A certain prism cut out of rock crystal changes right to left without displacing the image."* If the whole nervous system crossed like the decussating fibres of rock crystal, the change of the direction of the fibres would not, as far as it is consistent with present knowledge, give any advantage for forming separate centres and tracts; or even if a decussation of all the tracts of the several convolutions of each hemisphere took place at the base of the brain, or at the oblong medulla, the change by transferring the impulses for motion or sensation from one side to the other, is all that could be accomplished. But modifications of the arrangements of the tracts in crossing may nevertheless assist in surmounting difficulties that could not be so easily obviated by other means, and especially such as would require more numerous distinct centres for the purpose. The crossing is not a mere interchange of fibres between the two sides, but an altered arrangement capable of giving a new direction to the motions of the muscles, or to the image ascending from the retina.

If the crossing produces altered lateral motions as in some of the muscles more than in others, and serves for correcting the lateral inversion of the image on the retina, and for giving a lateral tendency

* Dr. Young's "Lectures on Natural Philosophy," vol. ii. p. 310.

to the motions of the chylo-poietic viscera, it would be unavailing to transfer its powers to all the other tracts and nerves, which have no such inverted impulses to receive, or do not require their mode of impression to be changed or modified.

EXPLANATION OF THE DIAGRAMS.

THE only positive inference to be correctly deduced from the position of the arched fibres of the optic tract, is that for allowing the mechanical adaptation of the eye to the anterior part of the skull. It appeared possible that the inverted image might also be corrected by the particular form of the fibres ; no proof, however, seemed to be afforded by any peculiarities in their origins or structure for such a purpose, but only in their bent form. It became, therefore, necessary to institute inquiries by figures or diagrams and other modes of calculation ; these, after very numerous trials, at length appeared sufficiently accurate for favouring the inference that the arched fibres also had relation to the correction of the inverted image.

The diagrams have been introduced for explaining the effects both of the arched fibres of the optic tract and the crossing at the optic commissure. The optic tracts have been represented both in their natural arched form, and as they have been straightened, or rather carried in an oblique direction from the opposite eye to the posterior part of the thalamus and the back of the head for exhibiting the correcting effects of the oblique and arched fibres, and the crossing in the optic commissure. It will be observed that when the uses ascribed to the oblique and arched fibres of the optic tract and thalamus are admitted to be present, the inverted images very readily acquire both their erect and lateral order, but when those arrangements either together or separately cease to be allowed,

there is a manifest aberration either in the erect or lateral compensations, or in both. In the diagrams, letters, and words, and figures have been employed because they can be so correctly defined and understood when they are depicted on the retina, any other objects could not have been used with the same facility and distinctness.

FIGURE I.

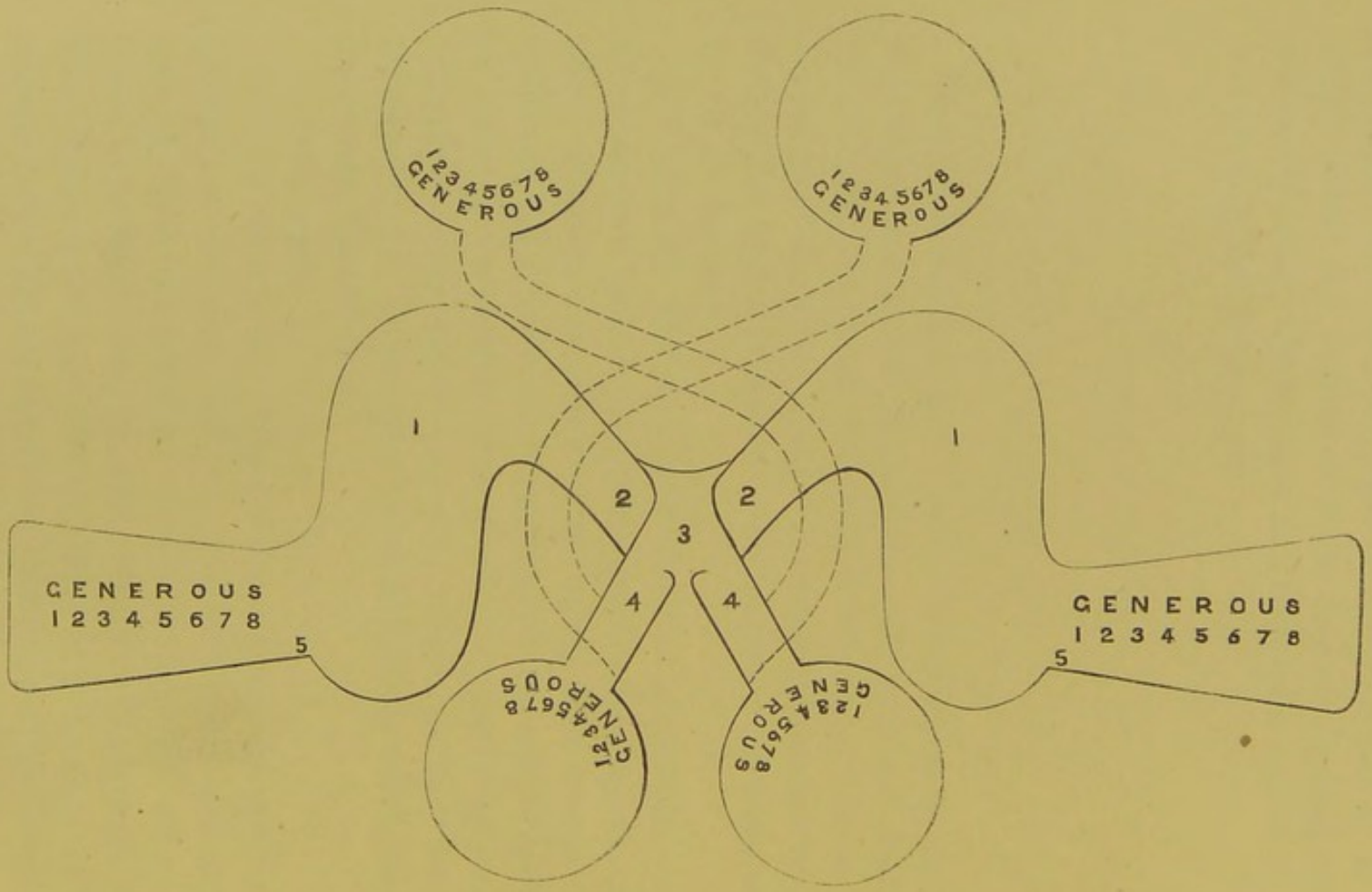
THIS figure has been drawn under the conviction that besides the oblique and arched fibres of the optic tract and thalamus for correcting the upright inversion of the image, there is also a crossing of the fibres through the optic commissure for correcting the lateral inversion. The following references serve for all the figures.

1. Thalamus. The superior oval surface of the thalamus by being extended backwards and downwards constitutes the optic tract ; it becomes connected in its course with several other eminences ; it is continued forwards at the base of the brain in an arched or semicircular form, which is supported by passing obliquely over the crus of the brain ; it joins the optic tract of the opposite side in the optic commissure, from which the two nerves issue for the eyes.

2. Optic tract.

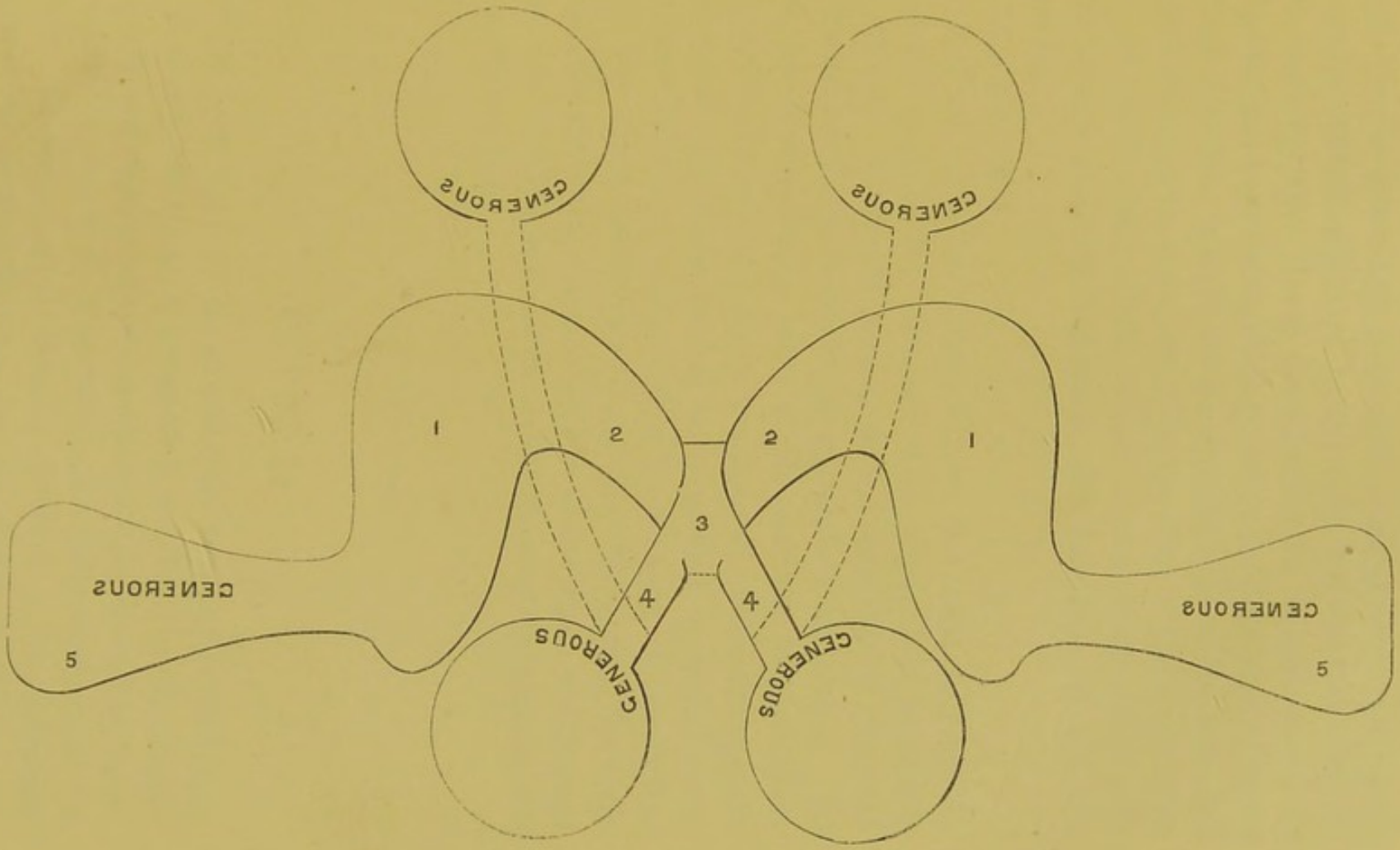
3. Optic commissure. The fibres composing the optic commissure not only cross, but have transverse combinations, the crossing fibres are considered as decussating each other obliquely in passing to their respective nerves on the opposite side. The fibres do not merely cross each other in proceeding to their respective optic nerves, but form combinations with the arched fibres of the optic tract for harmonising the varying shapes and combinations of the lateral with the upright position of the image in its ascent to the brain. As all the origins of the

FIGURE I.



GENEROUS.
12345678

FIGURE II.



GENEROUS.

optic nerve are contained in the optic tract of osseous fishes, and the nerves cross completely, it is probable that all the other origins proceeding from either hemisphere in the higher classes, although combined in the optic commissure, cross for the same purpose. From the examination of eyes wasted by disease, and their corresponding nerves to their origins in the brain, also from injuries to the eye and optic nerve, there is a great presumption in favour of the crossing of the optic nerve in the higher classes similar to that in osseous fishes, only with the modifications for combining the functions of the two nerves.

4. Optic nerve.

5. True visual tract beginning at the lower part of the anterior angle of the thalamus, with which it is intimately combined. It extends upwards on the outer side of the great commissure, to terminate in its appropriate convolution. Its locality at the anterior angle of the thalamus is particularly favourable for receiving the images from the retina through the optic tract and thalamus, and allowing them to ascend in the required order to be appreciated by the sensory. It constitutes the only direct communication between the retina, the optic tract, the thalamus, and convolutions of the brain, and there is no other ostensible medium for communicating the image to the sensory and mind.

FIGURE II.

THIS figure has been drawn under the supposition that there is no crossing in the optic commissure, and therefore the images are corrected as to their erect position, but by ascending to the same side of the brain from which the optic nerve takes its origin, the lateral aspect remains reversed. The difference between the distance from the bottom of the eye to the com-

mencement of the posterior part of the thalamus, would have been nearly one-third less if the optic nerve had been taken directly upwards on its own side; consequently there would have been very little space for correcting more than the upright inversion. The greater length gained for the optic nerve and tract by passing obliquely through the optic commissure allows a wider sweep, and therefore makes sufficient room for correcting the lateral as well as the upright inversion. The admitted image seems to take a sweep equivalent to nearly half a circle. The fibres in the optic nerve, tract, and crossing are probably so arranged and modified that the fresh image in ascending from the eye every time makes this half revolution, by which the inversion becomes instinctively corrected by help of the vital perceptive force inherent and peculiar to the optic nerve.

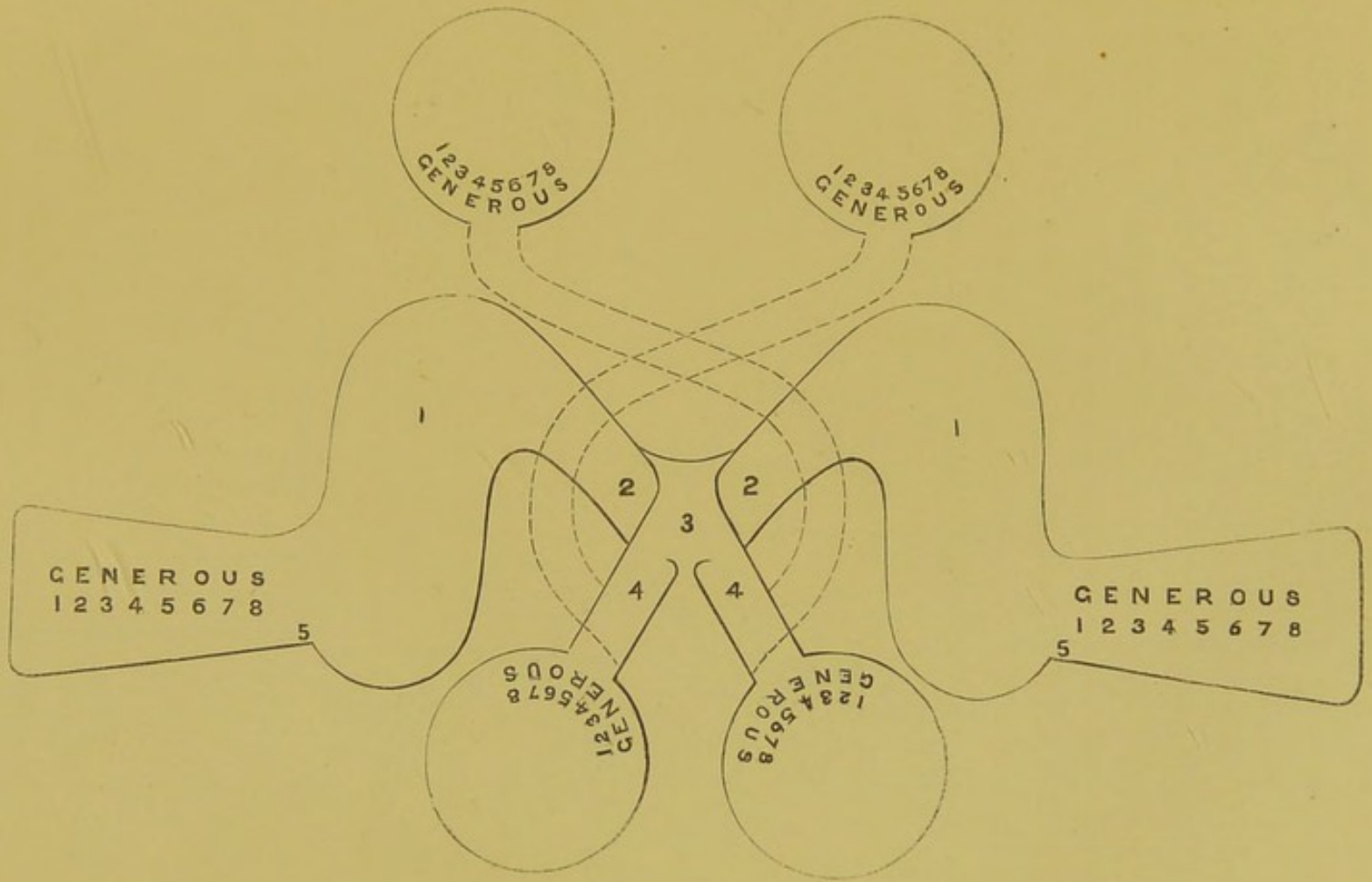
FIGURE III.

THIS figure has been drawn for showing both the upright and crossing correction. The word has been divided between the two eyes for explaining the manner in which it probably becomes conjoined in the brain through the commissures assisted by the voluntary influence of the muscles.

FIGURE IV.

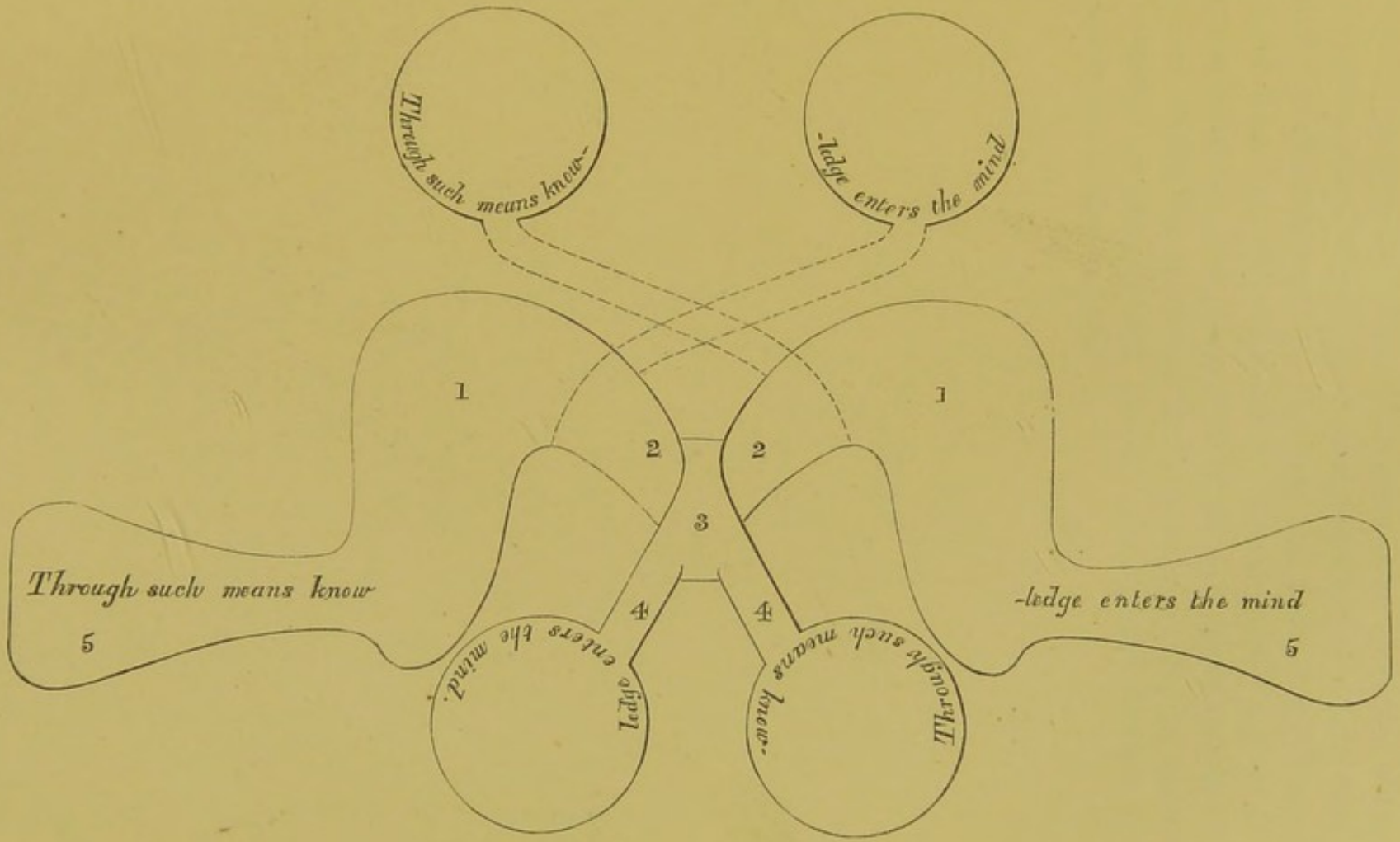
A SENTENCE has been divided between the two eyes for showing how continuously succeeding words may pass through the eyes to the brain with as much facility as single letters, and become conjoined in due order through the help of the voluntary muscles and commissures. Indeed, as letters and figures

FIGURE I.



GENEROUS.
12345678

FIGURE IV.



Through such means knowledge enters the mind.

and even whole words never fail of being regularly conveyed through the eyes and fibres of the brain in an appointed order, the process must be considered as approaching the right principle ; the diagrams not only showing the mode of impression of the images on the retina, but their semicircular motion in approaching the brain through their tracts to their appointed centres, if not the particular fibres of these centres by which the several portions of each image are conducted forward in their course to the intellect.

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