The seat of vision determined : and, by the discovery of a new function in the organ, a foundation laid for explaining its mechanism and the various phenomena, on principles hitherto unattempted / by Andrew Horn.

THE

SEAT OF VISION

DETERMINED;

AND,

BY THE DISCOVERY

OF A

New Function in the Organ,

A

FOUNDATION LAID

FOR

EXPLAINING ITS MECHANISM AND THE VARIOUS PHENOMENA, ON PRINCIPLES HITHERTO UNATTEMPTED.

BY ANDREW HORN.

Peculiare quiddam, naturæ subtilitate involutum delitescit, ægere fortassis, nisi perfectius explorato videndi modo detegendum. BARROW.

LONDON:

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ADVERTISEMENT.

THE following Essay respecting the *seat* of vision will be found interesting to the professional student, as well as the philosopher, by pointing out certain *new* functions in the eye, besides rectifying the optic image; but as the discovery leads to much important discussion, the author was induced to pursue the subject much further, under the following heads:—first, *the difference between the visible and tangible object;* secondly, *distance and magnitude;* thirdly, *the developement of a new theory of the mechanism of the or-*

gan in adjusting itself to objects at different distances; fourthly, *the manner in which the sensation of vision is produced;* fifthly, *single and double vision;* lastly, *miscellaneous phenomena*; all of which are treated in a manner entirely new. The two parts would compose a volume of about 400 pages, illustrated with plates. Should he meet with that encouragement for publishing the whole, which he has great reason to expect, it will be immediately put to the press.

The author has the satisfaction to state, that the work has already received the approbation of gentlemen highly respectable for science, whose names delicacy alone induces him to conceal.

ERRATA.

Page	Line	
26	6	*over* occurs instead of *even.*
42	11	*hotte* instead of *hot.*
59	3	*cyclides,* instead of *eyelids.*
60	3	from bottom, *prevails.*
72	4	*whence,* instead of *there*
93	9	from bottom, *oee ye,* instead of *one eye*
104	8	from bottom, *produce* wants an *s.*

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THE

SEAT OF VISION.

AMONG the various objects within the reach of human investigation, the eye is allowed to be a masterpiece—to bear in its structure, more visibly than any other part of organized matter, the impress of infinite intelligence. But it is to be lamented, that, after all the researches of philosophers, its mechanism is imperfectly known, and the manner in which many of the principal phenomena of vision are produced, is left, in every theory hitherto devised, vague and unsa-

tisfactory. Our professed object in the following essay is a further examination into this important part of physiology, and a solution of the difficult phenomena.

In order to accomplish what we here propose, it will be necessary to examine the principal parts that compose the organ ; their situation, structure, connection, and the manner in which they produce, or are affected by phenomena. Thus prosecuting the inquiry, we shall find, that the proper use of some parts of the eye has been mistaken, and the functions of other parts, essential to vision, have not yet been discovered ; consequently, the phenomena produced by their combined operation have remained inexplicable. Nor do we here hesitate to assert, that the grand difficulty and source of error, in the theory, lies in ignorance of the true seat of vision. Theorists have been deceived in their investigations, and

divided in their conclusions, by looking for the primary organ, in those parts of the eye which were designed to sustain but a secondary rank in the business of vision.

Every theorist is indebted to the labours of his precursors; they furnish him with a chart very necessary for the voyage of discovery he has undertaken. Even the wreck of former hypotheses is useful, pointing out, as so many beacons, those dangerous parts upon which he otherwise might founder.

The eye is justly considered as a natural achromatic instrument, or *camera obscura*, in which pictures of the external objects are painted upon the retina, by rays introduced through the aperture of the pupil. This is beautifully demonstrated by the famous discovery of Scheiner. If we take the eye of an ox, recently killed, and strip the sclerotic coat with the choroides from its poste-

rior portion, carefully preserving the retina as it lies upon the vitreous humour, and place the eye in a suitable aperture in the window shutter of a darkened chamber, with the cornea outwards, a transparent miniature painting of the external landscape, in all its variety of figures and colours, will be exhibited upon the retina. But this picture is inverted; so that they who are ignorant of the cause of the phenomenon will be surprised at seeing the head, where they expected the feet would be, and those objects painted on the left side, which they think ought, naturally, to have appeared on the right. In short, the whole scene appears, to every spectator, completely reversed by this experiment.

This inverted appearance of the picture on the retina, though agreeable to the laws of optics, involves an important question—how comes it to pass, since objects appear, *invertedly*, upon the retina of another eye, that every person per-

ceives the objects of vision that are in his own eye, in a different, or *erect* position? Ever since the inversion of the image was discovered by Kepler, the solution of this problem has proved a mighty difficulty in the theory of vision. Optical writers have been so embarrassed with the phenomenon, that some, in order to escape, have thrown the whole burden of the explication upon the shoulders of the metaphysician. It has been said, that to give an account how the mind is guided in its decisions, is not so much the business of the physiologist as of the metaphysician; since this involves an inquiry into the nature of the soul: for it is the soul that sees, and not the eye, which is only its instrument.

Such being the nature of the question, we are not surprized to find philosophers divided in opinion, as to the manner in which the sensation of erect vision is produced. The solution, first suggested by Kepler, has been approved by many:

namely, that the mind perceiving an impression made upon the lower part of the eye by a ray proceeding from the upper part of the object, naturally traces by its organ the ray back to its source, and necessarily determines that to be the top. In the same manner, the ray, that strikes the upper part of the eye, directs the mind in its judgment to the lower part of the object.

Descartes embraced this opinion, and illustrates it, by supposing a blind man to hold in his hands two sticks, that cross each other, while with these he touches the extremities of an object placed in a perpendicular situation. This man certainly will judge that to be the upper part of the object, which he touches with the stick held in the undermost hand, and that to be the lower part of the object, which he touches with the stick held in the uppermost hand. Descartes also supposes, that the notice which the soul takes of the object, does not depend on

any image, nor any action coming from the object, but merely on the situation of the minute parts of the brain whence the nerves arise: for instance, the particular situation of a capilament in the brain, which occasions the soul to see the point of an object in a right line with it.

Dr. Porterfield, in his Treatise on the Eye, advances the same hypothesis somewhat modified. The mind, according to this ingenious writer, never sees any picture painted on the retina, and consequently never judges of the object from what it observes in the picture: having before affirmed, that all our sensations are present with the mind and in the sensorium, he supposes that in seeing any object, the mind, by virtue of a connate and immutable law, to which it has always been subjected, traces back its own sensation from the sensorium to the retina, and from thence outwards, along right lines drawn perpendicularly from

every point of the retina, upon which any impression is made by the rays forming the picture, towards the object itself; by which means the mind or visive faculty does always see every point of the object not in the sensorium, or retina, but without the eye in these perpendicular lines: but these perpendicular lines nearly coincide with the axes of the several pencils of rays, that flow to the eye from the several points of the object; and since the mind, he says, has the power of judging the distance of objects, it follows from thence, that every point of the object must appear, and be seen in the place where it is; and consequently, the object must appear in its true erect position, notwithstanding its picture on the retina is inverted.

Dr. Priestley, adverting to Kepler's solution, justly remarks, that this hypothesis will hardly be deemed satisfactory. It seems sufficient, he thinks, to say that *upper* and *lower* are only relative terms;

and that, as all objects are painted on the retina in a similar manner (all the upper parts in one direction, and the lower in another,) it is by custom, founded on experience, and the association of ideas, that we learn to distinguish them one from another; so as to direct our eyes, or point our hands upward or downwards, as we have occasion. If this be the true solution, he says, it will follow, that if the images had always been painted in a different manner, that is erect, as the objects themselves are, we should have acted just as we do now, without being sensible of the difference, a different association of ideas only having taken place.

This explication of the difficulty, seems, indeed, countenanced by a contrivance of Dr. Hooke, consisting of convex glasses, for the benefit of short-sighted persons; which he described in a memoir read before the Royal Society, in which he observed, that by reason of the custom of seeing things inverted (which was the effect of this

instrument) it became as natural, as if they were seenerect; and he conceived, that if a person from his childhood were used to see things in this manner, and he should afterwards come to see them without the help of these glasses, he would fancy them to be inverted, as they really are at the bottom of the eye; as, he says, is very visible in the eye of a young cat, which is almost transparent at the bottom.

Philosophers are indebted to the celebrated Berkeley, Bishop of Cloyne, for the above metaphysical solution of the difficulty, respecting the inverted image upon the retina. The hypothesis is so ingenious, and has been received by so many optical writers, that, in justice to the author and our subject, I cannot easily avoid reciting it. After some apposite reflections upon a supposed case of a blind man, with regard to the judgments he would make of the situation of objects, and his ideas of upper and lower, Berkeley observes,

"That such an one, if we suppose him made to see, would not at first sight think, that any thing he saw, was high or low, erect or inverted; he would not think the things he perceived by sight were at any distance from him, or without his mind, the objects to which he had hitherto been used to apply the terms *up* and *down*, *high* and *low*, were such only as affected, or were some way perceived by his touch. But the proper objects of *vision*, make a new set of ideas, perfectly distinct, and different from the former; and which can in no manner, make themselves perceived by touch. There is, therefore, nothing at all that could induce him to think those terms applicable to them. Nor would he ever think it, till such time as he observed their connection with tangible objects, and the same prejudice begin to insinuate itself into his understanding, which from their infancy had grown up in the understandings of other men.

"To set this matter in a clearer light, I shall (says our author) make use of an example. Suppose the above-mentioned blind person do, by his touch, perceive a man to stand erect. Let us enquire into the manner of this. By the application of his hand to the several parts of the human body, he had perceived different tangible ideas, which being collected into sundry complex ones, have distinct names annexed to them. Thus one combination of a certain tangible figure, bulk, and consistency of parts, is called the head, another the hand, a third the foot, and so of the rest. All which complex ideas could, in his understanding, be made up only of ideas perceivable by touch. He had also by his touch, obtained an idea of earth or ground, towards which he perceives the parts of his body to have a natural tendency. Now, by *erect* nothing more being meant, than that perpendicular position of a man, wherein his feet are nearest to the earth: if the

blind person, by moving his hand over the parts of the man who stands before him, do perceive the tangible ideas that compose the head, to be farthest from, and those that compose the feet, to be nearest to, that other combination of tangible *ideas* which he calls *earth*: he will denominate that man erect. But if we suppose him on a sudden to receive his sight, and that he beheld a man standing before him; it is evident, in that case, he would neither judge the man he sees, to be *erect* nor inverted: for never having known those terms applied to any other, save tangible things, or which existed in the space without him; and what he sees neither being tangible, nor perceived as existing without, he could not know that in propriety of language, they were applicable to it.

"Afterwards upon turning his head or eyes up and down, to the right and left, he shall observe the visible objects

to change, and shall also attain to know, that they are called by the same names, and connected with objects perceived by touch: then, indeed, he will come to speak of them, and their situation, in the same terms that he has been used to apply to tangible things. And those that he perceives, by turning up his eyes, he will call *upper*, and those that he sees, by turning down his eyes, he will call *lower*."

Having illustrated, in various ways, the natural distinction between visible and tangible ideas, and shewn the manner in which they become connected, he says, " if we confine our thoughts to the proper objects of sight, the whole is plain and easy. The head is painted farthest from, and the feet nearest to the visible earth: and so they appear to be. What is there strange or unaccountable in this? Let us suppose the pictures in the fund of the eye, to be the immediate objects of sight; the con-

sequence is, that things should appear in the same posture in which they are painted. And is it not so? The head which is seen, seems farthest from the earth which is seen; and the feet, which are seen, seem nearest to the earth which is seen. And just so they are painted."

"But, say you, the picture of the man is *inverted*, and yet the appearance is erect. I ask, what mean you by the picture of the man; or, which is the same thing, the visible man's being inverted? You tell me it is inverted, because the heels are uppermost, and the head undermost. Explain me this. You say, that by the head's being undermost, you mean that it is nearest to the earth; and by the heels being uppermost, that they are farthest from the earth. I ask again, what earth you mean? You cannot mean the earth that is painted on the eye, or the visible earth. For the picture of the head is

farthest from the picture of the earth, and the picture of the feet nearest to the picture of the earth; and accordingly the visible head is farthest from the visible earth, and the visible feet nearest to it. It remains therefore, that you mean the tangible earth: and so determine the situation of visible things, with respect to tangible things, contrary to what we have demonstrated. For, from what has been premised, it is plain that the objects of sight and touch make, if I may so say, two sets of ideas, which are widely different from each other. To objects of either kind, we differently attribute the terms *high* and *low*, *right* and *left*, and such like, denoting the position and situation of things. But then we must well observe, that the position of any object is determined with respect only to objects of the same sense. We say any object of touch is high or low, according, as it is more or less distant from the tangible earth. And, in like manner, we determine any object of

sight *high* or *low*, in proportion as it is more or less distant from the visible earth."

When we reflect that the most eminent optical writers before Berkeley, had left the problem of erect vision without any satisfactory solution, it is nothing surprising to find this hypothesis embraced and defended by many distinguished philosophers. It is preferred by the judicious Dr. Smith in his Optics; and the celebrated Abbè Haüy gives it the preference in his Elementary Treatise on Philosophy, composed for the use of the students in the French National Lyceum. Such indeed is the ingenuity and address displayed by Berkeley in his essay, that no one who has paid the smallest attention to the subject of vision, but must admire the acumen of the ideal philosopher, in explicating a phenomenon, which, from its first discovery, seems to defy solution on any physical principle. And, it must be confessed, that if the first principles

of the ideal philosophy could be substantiated, that kind of distinction which he has formed between visible and tangible objects, would afford a beautiful explication of the problem respecting erect vision, as well as of some other phenomena equally inexplicable. But it will evidently appear, in the course of our inquiry, that the hypothesis of Berkeley, however ingenious, is a sort of illusion in the interpretation of nature, which our ignorance is ever ready to court—one of those hypothetical errors that we never can detect, but by confronting it with experience.

Dr. Reid, in his Inquiry into the Human Mind, enters profoundly into the nature of vision. He rejects the hypothesis of Berkeley respecting the inverted image; and, though he admires the distinction made by the idealist between the immediate and natural objects of sight, and the conclusions we are accustomed from infancy to draw from them,

yet he conceives that the mind, by the organ of vision, really notices the external object. Whatever is proposed by so sagacious a philosopher merits attention, whether our enquiries be after physical or metaphysical truth: if he do not always open a direct road to the object, he removes, at least, many surrounding obstacles that would have confined our view; and thus, in many instances, we are enabled from his labours, to judge with more certainty, in what direction truth is situated.

"When," says this able writer, "we propose the question, why objects are seen erect and not inverted? we take it for granted, that we are not in Bishop Berkeley's ideal world, but in that which men, who yield to the dictates of common sense, believe themselves to inhabit. We take it for granted, that the objects both of sight and touch are external, and have a certain figure, and certain position with regard to one another, and with

regard to our bodies, whether we perceive it or not.

"When," says he, "I hold my walking-cane upright in my hand, and look at it, I take it for granted, that I see and handle the same individual object. When I say, that I feel it erect, my meaning is, that I feel the head directed from the horizon, and the point directed towards it. I conceive the horizon is a fixed object, both of sight and touch, with relation to which, objects are said to be high or low, erect or inverted: and when the question is asked, why I see the object erect, and not inverted? It is the same as if you should ask, why I see it in that position which it really hath? Or why the eye shows the real position of objects, and doth not show them in an inverted position, as they are seen by a common astronomical telescope, or as their pictures are seen upon the eye when it is dissected?

"It will, without doubt, be allowed, that I see the whole object in the same manner, and by the same law, by which I see any one point of it. Now, I know it to be a fact, that in direct vision I see every point of the object in the direction of a right line that passeth from the centre of the eye, to that point of the object; and I know likewise, from optics, that the ray of light, that comes to the centre of my eye, passes on to the retina in the same direction. Hence, it appears to be a fact, that every point of the object is seen in the direction of a right line passing from the picture of that point on the retina, through the centre of the eye. As this is a fact, that holds universally, it must either be a law of nature, or the necessary consequence of some more general law of nature. And according to the just rules of philosophizing, we may hold it for a law of nature, until some more general law be discovered, whereof it is a necessary consequence; which I suspect never can be done.

"Thus we see that the phenomena of vision lead us by the hand to a law of nature, or a law of our constitution, of which law our seeing objects erect by inverted images, is a necessary consequence. For it necessarily follows, from the law we have mentioned, that the object, whose picture is lowest upon the retina, must be seen in the highest direction from the eye; and that the object whose picture is on the right of the retina, must be on the left: so that if the picture has been erect on the retina, we should have seen the object inverted." After paying a handsome compliment to Dr. Porterfield, as the discoverer of this law, he proceeds to illustrate its operation in various ways.

Berkeley's solution of the optical difficulty respecting the inversion of the image upon the retina is purely metaphysical; but the principles of the above hypothesis are mixed, being in part physical, and then terminating in a

metaphysical law. As we consider the subject to be entirely physical in its nature, any formal examination of Dr. Reid's reasoning would only retard our progress. We proceed, therefore, to notice a physical and more recent attempt towards rectifying the inverted image in the human eye.

Mr. Walker, in his Archives of Universal Science, has advanced an hypothesis, apparently more agreeable to the general laws and simplicity with which the operations of nature are conducted. He objects to the hypothesis of Berkeley as inconsistent with the usual course of nature. Nor does he approve of the opinion, though he prefers it as the more rational, which supposes the mind to rectify the image, by tracing back the rays that impress the retina to the object from whence they proceed, as if the impressions by which vision was effected were perfectly analogous to those of feeling. He very properly remarks, that the difference

of structure in the organs renders this inadmissible: the superficies of the body beingaccessible to impressions in every direction, but those made upon the retina are limited. The concave surface of this membrane not permitting it to be impressed, but in one direction by a straight line or direct ray; all the other rays that pass through the pupil making a diversity of impression, more or less faint or imperfect, as they fall nearer or farther from the axis of the eye. Hence the retina is deprived of the means of comparison and discrimination, so as to refer the rays, wherever they may impinge, to those objects that produce them.

Having made these objections to the different hypotheses that have been assumed to account for the phenomenon of erect vision, from an inverted impression upon the retina; Mr. Walker proceeds to explicate this "important point in the physiology of the eye, which has long puzzled philosophers. I however, (says

he,) conceive the question to be of very easy solution, and must suppose the eye to be acted on by light precisely, as some kinds of the reflecting telescope, which, after receiving the image inverted upon its interior lens, reflects and reverses it upon its exterior lens, and permits it to be seen in its natural situation. In the same way, the interior part of the retina, having received the image inverted, reflects, reverses, and presents it in its natural position upon its anterior part.

" The anatomical fact, that at the posterior part of the retina, its arrachnoid, pulpy, or more sensible laminæ is covered, on the side which is towards the vitreous humour, by a more consistent, vascular, and less sensible portion, while the anterior part is exquisitely delicate and fine, tends to confirm this theory. It receives also additional confirmation from the circumstance, that the transparent retina thus laid over the black pigmentum, and more especially over

of the tapitum, exclusively occupying this part in some of the inferior animals, must form the most perfect reflector.

" The physiological fact also, that the anterior part of the retina cannot be impressed over by a single direct ray, from without, and that, unless it receive the image reflected, reverted, and in its natural position from the posterior part, as I have described, it must be apparently useless, is almost a decided confirmation of the theory I have suggested.

" A confirmation (he says) of this theory, still more decided than these, yet remains. It appears that posteriorly the retina is entirely insensible, where the optic nerve enters, as at that part we have no sense of vision. An attempt has been made to account for this, by the entrance of the artery of the retina. But this has been found altogether inadequate, because the insensible portion of this nervous expansion is several times

larger, than that occupied by the artery, which, besides, sometimes enters in two branches, whereas this insensible spot suffers no variation. Consistently with the theory just delivered, I should conclude that we have, from this circumstance, a decided proof, that the posterior part of the retina is utterly insensible, at the entrance of the nerve, where it exists in the greatest quantity, it can be demonstrated to be so; and, that vision is wanting at this spot precisely, because, where the nerve enters, there are no choroids to reflect the rays to the sensible anterior portion. Thus, I conceive, (says he) the optic image is reverted."

This hypothesis is plausibly stated, but on examination it will be found essentially defective. If no other objection lay against it, there is one thing, at least, that should make us hesitate, before we receive it;—we find ourselves as much at a loss to comprehend, how these impressions made on that anterior sensible

portion, can be transmitted through the insensible posterior portion of the retina to the brain, as how an inverted image on its posterior part should produce a sensation, as if the impression were erect.

But the fallacy of the theory is so evident, that hypothetical objections are altogether unnecessary. The author has involved himself in a fundamental error, in supposing "that the posterior part of the retina, having received the image inverted, reflects, reverses, and presents it in its natural position on the anterior part." It is true, if the surface of the great cavity of the eye were uniform, that is, if the anterior portion presented, like the posterior, a continuous concavity uninterrupted by the aperture of the pupil, or if the theorist could have proved the capsule of the crystalline to be a *continuation* of the retina, the explication he proposes of this important optical difficulty might have been received as

the most satisfactory hitherto given. But, unfortunately, the anterior portion of the great cavity of the eye presents a configuration ruinous to the theory. It is evident, on the slightest inspection into the internal structure of the organ, that, although it could be demonstrated that the retina is the true seat of vision, and the anterior the most delicate part of this membrane, still, vision could not be accomplished in the manner supposed by the hypothesis; for it leaves an obscure space where vision is always found most distinct. The image, indeed, which a reflecting telescope exhibits, is not injured by the aperture in the centre: this is owing to two causes, first, to the smallness of the perforation, and then, to the image being produced by caustic rays. The case, however, is very different, when we suppose the anterior part of the retina *impressed* by the posterior picture. The capsule of the crystalline unquestionably is no propagation of the retina, consequently, a large blank is left by the hypothesis, in the *centre* of the field of

vision, equal to the diameter of the lens, upon which it is impossible that any impression can be made by the opposite pictures at the bottom of the eye. Now, as it is one of the most certain principles in vision, that none of the images in the field of view, except those formed in the centre, are distinct, this fact, therefore, without another remark, is sufficient to proscribe the hypothesis.

Ever since the discovery of Scheiner, the retina has been, very generally, considered an expansion of the medullary substance of the optic nerve. Nor was the fact, of its being the canvas upon which the pictures of the external objects are painted, ever questioned, till M. Mariotte, in the course of his investigations into the structure and mechanism of the organ, discovered that there is a certain spot in the eye insensible to the rays of light. In dissecting the organ, he had frequently observed that the optic nerve, not only in brutes but in man, was not situated in the axis of the

eye exactly opposite the pupil, but somewhat higher and nearer the nose. He was therefore induced to examine particularly into the reason of this structure, by throwing the image of an object upon this part of the eye. To effect this, he fastened upon a dark wall, parallel to his eyes, a small round paper, as a fixed point of sight, and he fastened another such paper on the right hand at the distance of about two feet, but rather lower than the former, that the light issuing might strike the optic nerve of the right eye, while his left was kept shut. He then placed himself over against the former paper, and withdrawing, by degrees, keeping his right eye fixed and very steady upon it; when he had retired about ten feet, he found that the second paper had entirely disappeared.

This, he says, could not be imputed to the oblique position of the second paper with respect to the eye, because he

could see more remote objects on the same side. The effect was such, as if the second paper had been conveyed away by slight of hand. He also made the experiment with his left eye while the right was kept shut; the second paper being placed on the left side of the point of sight; so that by the situation of the parts of the eye, it would not be doubted but that this defect of vision is in the optic nerve, where only the choroides is deficient.

Some ingenious improvements were afterwards made by Picard and Le Cat in the manner of performing this curious experiment; that of the latter we shall have occasion to notice in a future page.

A more easy method, however, of observing this surprizing phenomenon, than any of these is now generally practised. Let three pieces of paper, of about an inch in diameter, be fastened upon the side of a room, about two feet asunder,

and let a person place himself opposite to the middle paper, and beginning near it to retire gradually backward, all the while keeping one of his eyes shut, and the other turned obliquely towards the outside paper, which is against the covered eye; and he will find a situation (which is generally about five times the distance at which the papers are placed) where the middle paper will entirely disappear, while the two on the right and left will be plainly visible. The fact, however, is, that the real distance of the person from the papers has nothing to do with the experiment; it is the distance between the two objects that produces the effect. By a proper disposition of my eye, I have caused it frequently to lose sight of the moon, or some remarkable star. This experiment is represented by fig. 1, A, B, C, being the papers, D the optic nerve upon which B falls, and is invisible, while A, C, are distinctly seen.

The above surprising discovery of M.

Mariotte, produced a very interesting and protracted controversy among philosophers, respecting the seat of vision. This philosopher suspected, as the choroides is wanting, where the optic nerve enters the eye, that this membrane, and not the retina, was the principal organ of vision. Having maturely considered the subject, he communicated his suspicions to the Academy of Sciences, of which he was a member. The hypothesis was so specious, and supported by such arguments, that it was no sooner announced than embraced by many philosophers of the first distinction: for, supposing the choroides to be the chief seat of vision, not only is a curious fact in the structure of the eye explained, but a surprising phenomenon, otherwise inexplicable, is solved.

The claims of the retina, however, to the dignity of being the grand organ of vision, were not neglected. It was argued with equal ability on this side by

M. Pecquet and others, that the retina, and not the choroides, ought, for various reasons, to be regarded as the proper organ that receives the impressions of the rays of light, and communicates them by the optic nerve to the common sensory.

Mariotte, in support of his hypothesis, considered the transparency of the retina, a strong argument against the function usually assigned it. He observed that like air, or water, or the crystalline and other humours, it can receive little or no impression from the rays of light; like them, it must transmit the rays to another substance better qualified to receive and stop their impressions. He therefore concluded, that the opacity of the choroides, pervaded by the *pigmentum nigrum*, evidently points out its office, and shews that it is designed, by nature, to be the principal organ of vision.

He was further confirmed in his opinion of the small degree of sensibility in the

retina, and of the greater sensibility of the choroides, by observing that the pupil dilates itself in the shade, and contracts itself in a great light; which involuntary motion he thought a clear proof that the fibres of the iris are extremely sensible to the action of light; for this part of the eye is only a continuation of the choroides. He also thought that the dark colour of this membrane was intended to make it more susceptible of the impression of light.

In answer to Mariotte's observation concerning the transparency of the retina, Pecquet says, that it is very imperfectly so, much inferior to that of air or water, approaching nearer to the semi-transparency of oiled paper or horn used in lanterns. The opacity of the retina is such, that when the sclerotic coat and choroides are removed, objects cannot be distinctly seen through it. And if the retina be immersed in warm water, it appears white and almost destitute of transparen-

cy. He concludes, therefore, that while this opacity contributes to render vision more distinct upon the retina, it must prevent distinct impressions from being made upon the choroides; and contends, that any opacity in the retina would be as injurious to distinct impressions upon the choroides as if the crystalline and other humours which nature has always rendered transparent, were affected with the same degree of opacity.

With respect to the blackness of the choroides, which Mariotte thought necessary to the production of vision, Pecquet observes, that there is a great diversity of shades and colours in the choroides among the different species of animals, and even among individuals of mankind. In man and birds the colour is generally black; but in the eyes of lions, camels, bears, oxen, sheep, stags, dogs, and cats, with many other animals, the choroides exhibits upon the posterior part, which is most exposed to the light,

colours as resplendent as mother of pearl, forming a sort of tapitum or carpet upon its surface. Hence he infers, that if the rays of light really penetrated the retina, the choroides presents a superficies, that would effectually smother the impressions, and produce confused vision.

Mariotte replies, that the opacity of the retina is not great enough to prevent the rays from passing to the choroides in that quantity necessary for vision, but is merely sufficient to diminish their intensity, so as not to offend the membrane, when objects are very bright and luminous. Thus, the retina answers a purpose in the business of vision, similar to the scarfskin that is extended over the organ of feeling. Each is intended to protect its respective organ from injury.

Nor, will he allow Pecquet's argument to be conclusive, as to the appearance of the retina, when viewed, detached from the sclerotica and choroides; for

the state of the retina may be very different in a living body, and when examined in a dead subject. Things, he observes, by a relative change have their qualities changed: paper, when wetted, is transparent, but soon becomes opaque on being exposed to warm air; fat, which is transparent, when melted, grows opaque when cold; the cornea of the eye held for some time in hot air grows gradually less and less transparent, and at last becomes altogether opaque.

Mariotte observes, that the next argument for proving the retina opaque is likewise deceitful; for though, on being immersed in water, it appears white, yet it is not naturally so. The membrane covering the vitreous humour, though naturally transparent, yet when it is put into water, also appears whitish and opaque like a cobweb: the crystalline itself becomes muddy in water, and if it remains some time, grows opaque like snow. Experiments therefore after the

retina has been exposed to air, never can prove that it is opaque in living animals.

Hence, he thought, that experiments of a different kind were necessary, to ascertain whether light pass to the choroides in a sufficient quantity for vision, or be stopped by the retina. If the eye of an ox recently killed, and while hot, be divided transversely, so that a considerable portion of the vitreous humour may remain in the cavity, the colours of the choroides, the base of the optic nerve, and the trunk of the little vessels that proceed from thence, and their disposition, will be conspicuous through the thickness of the retina, so that it cannot be discerned whether there be a retina beyond the vitreous humour, or not. Thus light is found not only to pass the retina, but is reflected with sufficient strength to discover the choroides distinctly.

The transparency is rendered evident

by another experiment. If a person by night place his eye near a lighted candle, and cause a dog, at the distance of eight or ten paces from the candle, to be made to look at him, a bright light will appear in the eyes of the dog, which can proceed from nothing but the reflection of light from the candle, the image of which is painted on the choroides of the dog, which being of a light colour causes this strong reflection. If it proceeded from the crystalline, or retina, or farther surface of the vitreous humour, the eyes of men, birds, and other animals, would exhibit the same appearance; which never happens, because their choroides is black, and consequently, unfit for reflecting the light that falls upon it.

With regard to the other objection, which Pecquet urges from the diversity of colour in the choroides of different animals, Mariotte does not pretend to deny that in several creatures it is not black, but of some bright colour; he only af-

firms, that the blackness of the choroides, though not absolutely necessary for vision, yet is highly advantageous in rendering it more vivid and vigorous. The retina, he observes, can receive but a very faint impression from the light on account of its transparency; but the choroides, like all opaque bodies, must receive a stronger impression, and if black it will be proportionally stronger than any other colour. Black bodies grow hotte in the sun, and take fire sooner than bodies of any other colour, light acting more vigorously upon them. The cause, therefore, why man and birds see more distinctly than other animals, is the blackness of their choroides.

Another argument brought by Mariotte against the retina is, that this membrane is not composed of fibres, but that it is only a soft glue or mucus, which has no communication with the brain. But the choroides, which is a production of the pia mater, covers the optic nerve

beyond the eye, and accompanies the nerve throughout its source to the sensorium.

Pecquet, in answer to this, urges the opinion commonly received, that the retina is a continuation of the medullary substance of the nerve, and although it does, certainly, appear like a soft glue or mucus without fibre, yet this delicate texture is necessary to render it the more susceptible of the slightest impression from the rays of light.

Mariotte argues again in favour of the choroides, that, since the retina is not only transparent, but about half a line thick, this thickness renders it impossible that it should be the proper organ of vision. Distinct vision can only be accomplished, when the rays are brought to a point upon the organ. But upon whatever point the rays be supposed to fall upon the retina, whether at the surface next the vitreous humour, or that

next the choroides, or at any point between these, they must intersect each other, and confused vision will be the consequence. But on the contrary, the choroides, by its opacity, is evidently qualified for the production of distinct vision, since the rays all meet and are stopped at its surface.

To this Pecquet replies, that though it is necessary that the rays, which come from the different points of an object, should meet in so many corresponding points upon the organ of vision, yet these are not to be understood as mathematical, but physical points, which may occupy a space equal to the small thickness of the retina, without causing confusion: for the retina, he says, in man is scarcely thicker than ordinary paper; and in oxen, horses, deer, and other animals, which he examined, it never exceeds three or four leaves of paper, which is less than the fourth part of a line.

Mariotte, however, is not satisfied with this answer: he acknowledges that the point of the organ, where the rays are united, is a physical point; but he contends, that it is much smaller than any that can be perceived by sight; inasmuch as that the image of the object painted upon the organ is vastly smaller than the object itself, every point of that picture must be correspondently smaller than the point it represents; and therefore, since we can distinctly see very small objects, such as the minute ramifications of the arteries in the retina, the diameter of which does not exceed one-eighth of the thickness of that membrane, its image on the retina must be twenty-five or thirty times smaller; consequently, the thickness of the retina, though it were less than one-fourth of a line, is by no means proper for receiving such small images, and must produce a confusion in vision, as above explained.

The grand and concluding argument

assumed by Marriotte, in favour of the choroides, is taken from the insensibility of the organ where the optic nerve enters; for if vision were effected by the retina, he thinks, it ought to be produced wherever the retina is; and since the retina covers the whole of the nerve, as well as the rest of the bottom of the eye, there appears no cause why there should be no vision where the optic nerve enters the globe. On the contrary, if the choroides be the proper seat of vision, the cause is evident why there is no vision on the base of the nerve—the choroides, taking its rise at the circumference of its base, turns away from hence, and spreads itself over the whole concave surface of the globe, except at this particular spot.

Pecquet felt all the weight of this argument, and laboured very ingeniously to remove it. He supposes, that the fibres of the nerve next the centre terminate exactly at the extremity of its base, covering it, by expanding themselves

every way, similar to rays proceeding from the centre to the circumference: so that, according to this, none of the nervous fibres terminate in the extremity of the nerve, till they have proceeded as far as the circumference; and the other fibres of the nerve, more remote from the centre, do terminate in the retina, still farther and farther from the circumference of the nerve, according as they are at a greater or less distance from the centre. Thus, the whole outward surface of the retina is composed of the extremities of the nervous fibres, excepting the base of the nerve in which none of these fibres terminate. Hence, by supposing that there is no vision, except where the rays fall upon the extremities of the nervous fibres, he accounts for the insensibility of the retina where the nerve enters the eye.

But Mariotte observes, supposing it were necessary for vision, that the rays should fall upon the extremities of the

nervous fibres, of which, however, there is no proof, yet it is not to be imagined, that nature would have thus disposed the fibres of the nerve, so that none of them should terminate in the retina, at its base; since a simple continuation of these fibres to the anterior surface of the retina would have been sufficient for that purpose: whereas, according to Pecquet's hypothesis, they are carried still farther, even to the circumference of the base of the nerve, before any of them terminate; which is to make nature do something in vain, or rather to do something for no reason, but to produce a defect in vision.

Defeated in this, Pecquet proposed another hypothesis to explain the phenomenon; he imagined that the nervous fibres, which compose the retina, do terminate in this membrane, in like manner as the fibres of a plant terminate in its flower: hence, he concluded, that these fibres form a small cavity in the centre of the nerve, from which they begin to

expand themselves ; and that the rays of light fall perpendicularly upon the sensible parts of the retina, but falling obliquely upon this cavity, its fibres are not sufficiently agitated for causing vision.

This hypothesis Mariotte deems far from satisfactory. No such cavity has ever been observed, where the optic nerve enters the eye. Nor if it existed, does it follow, that it should be insensible ; for it is not necessary to vision, that the rays fall directly upon the organ, as Pecquet supposes ; it is sufficient, that all the rays that come from a point in the object, be reunited in a point on the organ : and, it is evident, that of all the rays, that converge to a point in the organ, there is only one ray that can directly fall upon it. All the other rays that enter the pupil besides, must terminate obliquely, yet this never produces any defect of sight ; consequently the defect of vision, at the base of the nerve, is not occasioned by the obliquity of the rays that fall upon this spot.

The author of these hypotheses at last resorted to a physical fact for the solution of this phenomenon, so perplexing to those who plead for the retina as the chief organ of vision. Anatomists having observed, that with the nerve certain blood-vessels enter the eye, which are afterwards divided into minute capillary ramifications, that are distributed through the retina: hence, he says, the insensibility of the retina, where the optic enters, is no argument against its being the immediate organ of vision, because in that place the rays of light do not fall upon its nervous fibres, but upon the blood-vessels, which are large enough for occasioning that defect in our sight.

In answer to this Mariotte admits the fact, that some blood-vessels do enter the eye along with the nerve; but affirms they are evidently too small to prevent vision throughout the nerve, the diameter of each occupying a space not more than one-eighth of the diameter of the insensible

part of the nerve: he therefore concludes, that the portion of the retina, answering to the whole base of the nerve, could never be rendered insensible by such small vessels, which could only make us lose sight of a paper of two inches diameter, at most, at the distance of ten feet: and, when two vessels enter the eye, as it sometimes happens, we ought to lose sight of two small papers correspondent to these little vessels upon which the image falls, and at the same time see distinctly the space between them; which is contrary to experience; for the defect of vision is always continued, and corresponds with the entire base of the nerve. Hence, he concludes, that the choroides is the immediate organ of vision, and that the defect of sight where the optic nerve enters the eye, is solely owing to the want of this membrane.

Such being the state of the controversy, we are not surprised to find some eminent philosophers not fully satisfied with either hypothesis. De la Hire,

though he took part with Pecquet, arguing in favour of the retina from the analogy of the senses, in all of which the nerves are the proper seat of sensation, supposes that our defect of vision, where the optic nerve enters, cannot be attributed to the blood-vessels, or any thing else, but to the want of the choroides: still he does not allow this membrane to be the principal organ of vision; for he thinks it absurd to search for the organ of any sense but in the nerve. He considers the retina as an expansion of the optic nerve to be the proper organ, but that it does not receive the impression necessary for producing vision, immediately, from the rays themselves: they first penetrate the transparent retina, and, when stopped by the opacity of the choroides, agitate this membrane. These agitations, excited in the choroides, are communicated to the retina that lies upon it; so from hence they are transmitted to the sensorium, by the fibres of the optic nerve, of which the retina is an xpansion.

On the other hand, Mr. Michell suggested to Dr. Priestley, when composing his History of Vision, a number of additional arguments in favour of the choroides, as being the immediate organ of vision, which had escaped its former advocates. He observes, that, in order to distinct vision, the pencils of rays, which issue from the several points of any object, must be collected either accurately, or at least, very nearly to corresponding points in the eye, which can only be done upon some uniform surface. But the retina being of a considerable thickness, and the whole of it being uniformly nervous, and, at least, nearly, if not perfectly transparent, presents no particular surface; so that, in whatever part of it the pencils be supposed to have their foci, the rays belonging to them will be separated from one another, either before or after they arrive there, and consequently vision will be confused.

If the seat of vision be supposed at the nearer surface of the retina, he supposes

that the light reflected by the choroides, in those animals which have this membrane white, or coloured, would produce a confusion of images. On the other hand, it would be impossible that vision should be performed at this place by light, reflected from the choroides, because in many animals it is perfectly black, and reflects no light at all; and yet such animals see even more perfectly than others.

If the seat of vision be at the farther surface of the retina, and it be performed by direct rays, a white choroides could be of no use; and if it were by reflected rays, a black one could not answer the purpose.

It is likewise an argument in favour of the choroides being the organ of vision, that it is a substance, which receives a more distinct impression from the rays of light, than any other membrane in the animal system, excepting the white cuticle, which lies under the scales of

fishes; whereas the retina is a substance on which light makes an exceedingly faint impression, and perhaps no impression at all; since light, in passing out of one transparent medium into another immediately contiguous to it, suffers no refraction or reflection, nor are any of the rays absorbed, unless there is some difference in the refracting power of the two media, which probably is not the case between the retina and vitreous humour, which is in contact with it. And wherever the light is not affected by the medium it falls upon, we can hardly suppose the medium to receive any impression from the light, the action being probably always mutual and reciprocal.

Besides, the retina is so situated, as to be exposed to many rays besides those which terminate in it, and which, therefore, cannot be subservient to vision if it be performed there. Now this is not the case with the choroides, which is in

no case transparent, and has no reflecting substance beyond it.

He thinks it also peculiarly favourable to the hypothesis of the seat of vision being in the choroides, that we can then see a sufficient reason for the diversity of its colours in different animals, according as they are circumstanced with respect to vision. In all terrestrial animals, which have occasion to use their eyes by night, the choroides is either of a bright white, or some vivid colour which reflects the light very strongly. On this account vision may be performed with less light, but it cannot be with great distinctness, the reflection of the rays doubling their effect; since it must extend over some space, all reflection being at a distance from the reflecting body.

On the contrary, the choroides of birds in general, especially eagles, hawks, and other birds of prey, is black; by which means they are able to see with the

greatest distinctness, but only in bright day-light. The owl, however, seeking her food by night, has the choroides white, like the cat. Lastly, in the eyes of man, which are adapted to various uses, the choroides is neither so black as that of birds, nor so white as that of those animals, which make the greatest use of their eyes in the night.

As to the hypothesis of De la Hire, Mr. Michell observes, that the perceptions can hardly be supposed to be so acute, when the nerves, which are the chief instruments of sensation, do not receive the impressions immediately, but only after they have been communicated to another substance: besides, it must be more natural to suppose that, when the principal impression is made upon the choroides, that it is communicated to the brain, by its own proper nerves, which are abundantly sufficient for the purpose.

I must own, says Dr. Priestley, that,

after having retained my prejudice in favour of the retina, notwithstanding all that was advanced by M. Mariotte, and the advocates for his opinion among his countrymen, the arguments of Mr. Michell, in favour of the choroides, have more weight with me, than I was at first either able to perceive, or willing to acknowledge, in those of the French philosophers.

The learned author, however, towards the conclusion of his history, in an additional section relative to the proper seat of vision, gives up his opinion of the choroides, as the principal organ; after several miscellaneous observations, he seems inclined to fall in with the hypothesis of De la Hire; whose argument in favour of the retina, from the analogy of the senses, he says, is much strengthened, by considering, that the retina is a large nervous apparatus, immediately exposed to the impression of light; whereas the choroides receives but a

slender supply of nerves, in common with the sclerotica, the conjunctiva, and the cyclides, and that its nerves are much less exposed to light than the naked fibres of the optic nerve. Indeed, from anatomical considerations, one might imagine that any other part of the body was as sensible of the impressions of light, as the choroides.

He concludes these remarks with observing that, if the retina be as transparent as it is generally represented to be, so that the terminations of the rays must necessarily be either upon the choroides, or some other opaque substance interposed between it and the retina, the action and reaction occasioned by the rays of light being at the common surface of this body and the retina, both these mediums (supposing them to be equally sensible to the impression of light) may be equally affected; but the retina being much more sensible to this kind of impression, may be the only in-

strument by which the sensation is carried to the brain, though the choroides, or black substance with which it is lined, may also be absolutely necessary for the purpose of vision. Indeed, when the reflection of light is made at the common boundary of any two mediums, it is with no propriety that the effect is ascribed to one of them rather than the other; and the strongest reflections are often made back into the densest mediums, when they have been contiguous to the rarest, or even to a vacuum. This is not far, he says, from the hypothesis of De la Hire, and will completely account for the entire defect of vision at the insertion of the optic nerve.

The zeal with which these discussions have been conducted, and the ability with which a diversity of opinion has been maintained, are sufficient proofs of the uncertainty that pre ils respecting the proper seat of vision, as well as of the importance philosophers have con-

stantly attached to the discovery. How far any of the above hypotheses may have satisfied the reader, I cannot determine: all of them, however, appear to me extremely hypothetical and unsatisfactory. The most that can be said in their favour is, that each hypothesis seems more indebted to the intricacy of the subject, and the ingenuity of its author, for any favourable reception it has experienced, than to physical demonstration. In some cases, when direct evidence cannot be obtained, the inquirer may embrace that opinion, which appears to him the most probable upon the subject, and proceed, without much interruption, in his investigations. This, however, as it respects the seat of vision, is very difficult, if not impossible; the evidence and authorities being so equally balanced between the retina and choroides, that we find some eminent philosophers staggered, and desirous of compromising the respective claims of these two membranes to the chief function of vision.

Besides, another thing extremely embarrassing in our inquiries into this subject is, that we find even those who contend for the retina being an expansion of the optic nerve, expressing themselves either doubtfully, as to its use, or at open variance with each other, respecting the structure, and requisite sensibility of this membrane.

Haller, rejecting the hypothesis that goes to establish the choroides as the proper instrument of vision, speaks of a certain fibrous membrane in the retina, distinct from its pulpy substance, and supposes that on these fibres the images of the objects are painted.

We have reason, says Dr. Reid, to believe that the rays of light make some impression upon the retina; but we are not conscious of this impression; nor have anatomists or philosophers been able to discover the nature and effects of it; whether it produce a vibration in

the nerve, or motion of some subtile fluid in the nerve, or something different from either, to which we cannot give a name.

Something (says Dr. Priestley, among other *desiderata* mentioned at the end of his history) may be added more decisive for, or against the retina, being the place where the pencils of rays terminate; or, in other words, being the seat of vision, than has as yet been advanced by the advocates, for either of the opinions.

The generality of optical writers, however, agree with Dr. Porterfield, that the retina is the true seat of vision; and, though it is expanded over the whole concave surface of the eye as far as the *ligumentum ciliare*, yet it is not all equally sensible.

"This appears, evidently (says this ingenious writer) when we view any long word, such as *Mathematician;* for if the

eye be directed to the first letter M, and kept fixed thereon, for observing it accurately, the other letters, especially those towards the end of the word, will not at the same time appear clear and distinct. The reason of which is, because the pencils of rays, that come therefrom, fall too obliquely upon the eye, to be accurately collected in distinct points upon the retina; but chiefly because of a certain degree of hardness, callosity, or insensibility in all parts of the retina, excepting towards the axis of the eye, directly opposite the pupil. Hence it is, that, when we view any object, we turn our eyes directly towards it, that its picture may fall precisely upon that most delicate and sensible part of the retina, which is naturally in the axis of the eye; but if this most sensible and delicate part of the retina should, from a fault in the first formation, or from any other cause, happen to be placed, not in the axis of the eye, but a little off at one side, then, to see any object distinctly,

and thence to receive the strongest, and most lively impressions, the eye must not be directed towards it, but a little to one side, that the object may have its picture made upon the most sensible and delicate part of the organ."

After reviewing the controversy about the retina, and examining some other opinions respecting the seat of vision, he says, "In order to find something probable in so difficult a matter, we must consider that vision consists of impressions made upon the organ of sight, infinitely more slight and delicate than impressions made upon the other organs of sense; and, therefore, that the organ might be susceptible of these weak impressions, it was necessary that it should be endowed with a substance exquisitely delicate and tender: and this may be the reason why the retina is made so soft and tender, that it appears like the medullary part of the nerve, dissolved into a sort of soft glue or mucus. Now, it is very probable that

the defect in our sight, where the optic nerve enters the globe, proceeds from the hardness and callosity of the retina in that place, which has not yet acquired that softness and delicacy that is necessary for receiving so slight impressions as those of the rays of light; for the retina is always a great deal more soft and tender than the medullary part of the nerve of which it is formed, excepting where it covers the *base* of the nerve, which still retains something of that firmness which it had in the nerve, by which it is rendered unfit for being sufficiently agitated by the faint impressions of light. And this we take to be the reason why that part of our retina is insensible where the optic nerve enters."

But this opinion, respecting the texture and most sensible portion of the retina is directly contradicted by the more recent hypothesis of Mr. Walker: towards the close of his disquisition upon vision, which we have already noticed, this author, in language equally positive

says, " Consistently with the theory just delivered, I should conclude, that we have from this circumstance, a decided proof that the *posterior* part of the retina is *utterly insensible*, since at the entrance of the nerve, where it exists in the greatest quantity, it can be demonstrated to be so; and that vision is wanting at this spot precisely, because where the nerve enters there is no choroides to reflect the rays to the *sensible anterior* portion."

I consider it altogether unnecessary to detain the reader by any animadversion upon these undecisive and contradictory opinions. From the view we have now taken of the different hypotheses assumed concerning the seat of vision, and the particular sensibility of the retina, the immediate inference that every unprejudiced enquirer must draw is, that their respective authors must have laboured under some extraordinary deception in their investigations: alike uncertain as to the texture and use of this membrane,

each seems to have found himself, no doubt, from the recondite nature of the subject, perfectly at liberty to accommodate its character to his own hypothesis. These remarks shall suffice; for it is not so much our business to demolish the theories of other men, as to remove such obstacles only as might obstruct the erection of our own.

"It is evident," says Dr. Reid, "that the pictures upon the retina are, by the laws of nature, a mean of vision, but in what way they accomplish their end, we are totally ignorant.—We can give no reason why the retina is, of all parts of the body, the only one in which pictures made by the rays of light cause vision, and therefore we must resolve this solely into a law of our constitution. And, according to the just rules of philosophizing, we may hold it for a law of nature, that every point of the object is seen in the direction of a right line, passing from the picture of that point on the retina through the

centre of the eye, until some more general law be discovered, which, I suspect, can never be done."

After the laborious investigations of so many eminent philosophers, and the conclusion here drawn by one who had profoundly examined the principles and phenomena of vision, it will perhaps be deemed a high degree of presumption in me to have resumed these subjects. The only apology I have to offer for the attempt, is what most men feel whose minds are formed for reflection—an insatiable desire to trace the causes of things; which is frequently stimulated at the sight of those difficulties that deterred others from the pursuit. This active principle is operating in the mind of my reader: that which now urges him to pursue the subject of vision in this essay, originally incited the author to the undertaking. To this disposition of mind, therefore, and to this alone, must be attributed my entering upon, and pursuing an enquiry

into the structure of the organ, its mechanism, and phenomena of vision, after philosophers of the first rank had abandoned it with sentiments little short of despair.

Anatomists have shewn us that the optic nerve possesses two principal tunics that envelope its medullary substance; the exterior, derived from the dura mater, which forms, by its expansion, the sclerotic coat of the eye, and the interior, which is a continuation of the pia mater, and is expanded on entering the globe, by which it forms the choroides. The retina, or innermost coat of the eye, is supposed to be a propagation of the nervous substance. Thus the entire trunk of the optic nerve seems naturally expanded into the principal coats that compose the globe of the eye.

Now, however natural this arrangement of parts may appear, by representing the three grand portions that com-

pose the shell of the eye, as proceeding from the three principal substances which constitute the optic nerve; yet, I conceive the fact, as far as it relates to the retina, to be very questionable. Having made this assertion, I shall immediately proceed to assign the reasons which operated upon my mind, so powerfully as to induce me to deviate in opinion from so many eminent anatomists and philosophers that have written upon the organ and nature of vision.

In the first place, then, the controversy so ably carried on, without deciding the question, whether the retina or the choroides be the principal organ of vision, leaves the subject still in suspense. The facts that appear against the retina are weighty; and our doubts are strongly confirmed, by the contradictory opinions that prevail among physiologists, respecting the proper texture of this membrane. To say nothing of these inadequate hypotheses invented by Pecquet, to account for its insensibility upon the base of the

nerve, some of its advocates strenuously insist, that the retina is every where insensible to the impression of light, except at the *axis* of the eye, whence they pronounce it to be most exquisitely *sensible*. Others, with equal confidence, affirm, that it is totally *insensible* at the *axis*, and confine its sensibility entirely to its *anterior* portion. On the contrary, Mariotte and others, who plead for the choroides, assert, that the retina is *insensible throughout its whole structure*. Le Cat, who held that the *pia mater*, and not the nerves, themselves, is the proper instrument of sensation, supposes, that the retina answers a purpose similar to the *scarfskin* covering the papillæ pyramidales, which are the immediate organ of feeling, or that of the porous membrane, which covers the glandulous papillæ of the tongue. The retina, he says, receives the impressions of the rays, moderates, and prepares them for the proper organ, but is *itself insensible* to any impression from the rays of light.

In the second place, it appears highly unreasonable to suppose so large a mass, as the medullary substance of the optic nerve, necessary for the production of a membrane so very thin and delicate, as the retina appears to be in its texture. This is to represent the allwise Creator making a useless provision—doing something superfluous and in vain. Some proportion certainly is discoverable between the sclerotic coat and the *dura mater;* and also between the *pia mater* and the choroid membrane; but can any necessary correspondence be discovered, between the volume of matter contained in the trunk of the optic nerve, and the small quantity requisite to form that thin lining for the choroides, called the retina.

Lastly, no useful purpose has ever yet been assigned, nor can possibly be conceived to arise from leaving a spot in the organ, equal to the base of the nerve, destitute of the choroides, and insensible to impression from the rays of light.

Besides, to impute either a partial, or total insensibility to any disposition of a substance, which is allowed by all physiologists to be the grand medium in the animal œconomy, through which impressions made on the organs of sense are transmitted to the common sensory, is, to say the most for it, an unaccountable anomaly in the nervous system. Nor will the opinion of some anatomists, if true, that the nails, which are well known to be devoid of sensation, are a continuation of the nervous substance, at all affect our argument; for, in this case, the insensibility is at the extremities of the nerves, whereas in the retina it lies between the most sensible part and the brain; so that all the impressions must, somehow, find their way through this insensible portion, before they can reach the sensorium. When told, that the retina is an expansion of the medullary substance, and that this membrane is totally insensible at the base of the optic nerve, where it originates, we ought to be, almost, as much surprised at this, as

if it were affirmed, that the rays of light produce less effect at the focus of a burning glass, than when scattered over its surface.

It is true, were we to adopt the hypothesis of Mr. Michell, we might, at once, get rid of the difficulty; but then we should involve ourselves in another, not less perplexing: For, if we suppose the proper nerves of the choroides sufficient to transmit the impressions of visible objects to the brain, then, the most remarkable nerves in the system are improperly named *optic*—whatever the nerve may contribute to the formation of the globe, it is rendered, by this hypothesis, totally useless in the business of vision.

But it may be said, in reply to all that has been advanced, "Though we cannot assign the reason why it is so, still, a total want of sensibility at the base of the nerve is a fact that cannot be denied—it is actually demonstrated by the expe-

riment of Mariotte." True, but it does not follow as a consequence, that the cause of this defect in the organ lies in the retina. We shall find that in this, as in many other parts of physiology, a precipitate desire of knowing solicits our credulity to embrace a false hypothesis, rather than acknowledge ourselves ignorant of the true cause of the phenomenon.

I am well assured the more any one examines the subject, the more will he be convinced that insuperable obstacles, to a satisfactory theory of vision, exist in the first principles of every hypothesis hitherto framed. Impressed with this fact, I suspected, that "something involved in the subtilty of nature" lay hid in the structure of the organ; and that the phenomena of vision never could be satisfactorily explained, till this was discovered. That I am not singular in this opinion is evident from the language of Dr. Reid:

"We know not well (says this writer) what is the office of the optic nerve, nor in what manner it performs that office; but that it has some part in the faculty of seeing, seems to be certain; because in an *amaurosis*, which is believed to be a disorder of the optic nerves, the pictures on the retina are clear and distinct, and yet there is no vision.

"We know still less of the use and function of the choroid membrane; but it seems likewise necessary to vision: for it is well known, that pictures upon that part of the retina, where it is not covered by the choroid, I mean at the entrance of the optic nerve, produce no vision, any more than a picture upon the hand. We acknowledge, therefore, that the retina is not the last and most immediate instrument of the mind in vision. There are other material organs, whose operation is necessary to seeing, even after the pictures upon the retina are formed. If ever we come to know the struc-

ture and use of the choroid membrane, the optic nerve, and the brain; and what impressions are made upon them by means of the pictures upon the retina, some more links of the chain may be brought within our view, and a more general law of vision discovered; but while we know so little of the nature and office of these more immediate instruments of vision, it seems impossible to trace its laws beyond the pictures upon the retina."

Thus sanctioned in my suspicions, but at the same time discouraged in my attempts, by the opinion of a writer no less distinguished by his judicious disquisitions upon this branch of philosophy, than for his metaphysical speculations, I, for a period, dropped the inquiry.

The subject, however, some considerable time afterwards, happened to present itself with increased importance; I therefore resolved to proceed, in the best man-

ner I could, in so intricate an investigation. I conceived the first step would be to discover, if possible, the real structure of the retina, as connected with that remarkable insensibility supposed to exist in this membrane at the entrance of the optic nerve. Adopting the experiment of Pecquet, I plunged the retina into tepid water. In this state I examined the retinæ of several oxen ; thinking, by this process, such a change might be produced, as that some part of the membrane would possibly exhibit an appearance more whitish, opaque, or clearer than the rest. But, after attentively examining them with a magnifier, I could discover no symptom whatever, either towards the axis, or in any other direction of these retina, that indicated any thing like that superior sensibility so vaguely described by optical writers. I next procured the eyes warm from the animal, and examined the retinæ as they lay upon the vitreous humour ; but in this, as in the former experiment, I was unable to discover the least appearance of

greater delicacy or opacity in any one part of the membrane than in another; each retina exhibited an uniform transparency throughout its whole structure.

Having made these experiments, and reflecting upon the contradictory descriptions given of this membrane by physiologists, with the indefinite manner in which each hypothesis is expressed, the most strenuous advocate for the retina will scarcely accuse me of precipitancy, when I totally rejected its claim to the chief function in vision. Since its insensibility, in one part, is plainly demonstrated by the experiment of Mariotte, the following conclusion I think unavoidable—that the sensibility of this membrane to the impression of light is entirely hypothetical; therefore, as its insensibility has been proved, it cannot be a production of the medullary substance of the optic nerve.

I am aware of an objection that may be started to this inference: it may be

said, since the outer coat, which the nerve derives from the dura mater, goes to the formation of the sclerotica, and the choroides is a real propagation of the second coat of the nerve, no other part remains to be assigned, as the source of the retina, except the medullary substance of the nerve, which proceeds immediately from the brain; therefore, notwithstanding its insensibility at the base of the nerve, we have the greatest reason to believe the retina to be the true seat of vision.

We have already observed, among other reasons for questioning the nervous origin and structure of the retina, the very great disproportion between the quantity of matter in its composition, and that contained within the trunk of the optic nerve; therefore, from the delicacy, consistence, and uniform appearance exhibited by this membrane, which is that of a soft glue or mucus, I was led to consider it as nothing else than an expansion of

the *scepta* or membranous substance that pervades the optic nerve. I was the more confirmed in this opinion, by the manner in which the retina is attached to the base of the nerve. It has just that kind of adhesion which we might expect to find in a propagation of the *scepta;* for the medullary substance is never wounded when an incision is made, in order to detach this membrane from the nerve.

Persuaded, therefore, that I had actually discovered the true origin of the retina, and that it had in consequence lost all claim to superior sensibility, and to the principal function in vision, I was induced, from a general survey of the organ, to conclude that the sole use of this transparent membrane in the mechanism of vision is to produce reflection, in a manner similar to the polished surface of a metallic reflector, or perhaps it might, with more propriety, be compared to glass, the choroides behind answering the purpose of the metallic coating upon the convex surface of a mirror.

A question immediately arises from this unusual representation of the internal structure of the organ—If the retina really is not an expansion of the nervous substance, in what manner is vision produced?

In answering this question I shall lead the reader nearly in the same tract which I pursued in the developement of this important and hitherto inexplicable problem. We shall therefore begin by taking a survey of the structure, disposition, &c. of the optic nerves, to the neglect of which, we presume, our imperfect knowledge of vision is chiefly to be attributed.

The nerves are universally allowed to be the chief instruments of sensation in the animal œconomy. If a nerve be divided, or a ligature made round a nerve leading to the muscles, its power of action in the one case is suspended, and in the other destroyed. The most remarkable

pair in the nervous system are the *optici;* whether we consider them as to magnitude, disposition, termination, or use. They take their rise from certain protuberances in the brain, which anatomists distinguish by the name of *thalami nervorum opticorum;* from thence they descend towards the base of the skull, in a manner as if they would cross each other; but having approached, without any intersection, or confusion of substance, they separate, and, continuing their angular direction, proceed forward, till each nerve passes out of the skull into the orbit of its respective eye by a hole in the bottom; here each receives a covering from the dura mater, the expansions of this and the pia mater form the globe of the eye, while the whole nervous substance of each trunk perforates its proper globe, not exactly in the axis, but a little higher and nearer the nose. The optic nerves are further distinguished as the largest pair that arise from the brain; each nerve in the human eye being, at a

medium, about one-sixth of an inch in diameter.

In prosecuting this inquiry several circumstances contributed to direct my attention to the optic nerve, as the grand organ of vision. In surveying the general structure of the eye, I was particularly struck with the magnitude of this nerve, and the singular manner of its termination in the concave surface of the globe. The *optici* do not, like every other pair of nerves, terminate in branches: they are the largest in the system, yet the entire nervous substance *perforates* the globe *perpendicularly*, presenting in its concavity a well defined *circular base* fringed with the choroides, and covered with the retina. This base was not only rendered remarkably distinct, by the following experiment, but at the same time I observed a beautiful effect produced by light upon the nerve. Having procured the eye of an ox recently killed, after dividing it transversely, and abstracting the

vitreous humour from its posterior portion, leaving about four lines of the nerve attached, I placed the segment of the globe in a suitable aperture made in a window-shutter, with the concave surface inwards. Thus situated, having darkened the chamber, the base of the nerve exhibited, in its little hemisphere, an appearance beautifully distinct and luminous, having a striking resemblance to the sun, as seen through one of those brownish fogs with which the atmosphere is sometimes charged in the winter season. The light, which produced this phenomenon, must have pervaded the whole extent of the nerve; for being completely inclosed by the muscles and fat, it was impossible that any lateral light could have contributed to the appearance. The same phenomenon may be seen, though with less effect, by holding a similar portion of the globe between the eye and a lighted candle.

The reader must have anticipated, and therefore, will now readily comprehend

the manner in which I conceive vision to be accomplished. Rays, from all points of such objects as are opposed to the organ, pass through the pupil, and, after refraction in the different humours, delineate perfect, but inverted pictures upon the retina at the bottom of the eye; these pictures are instantly reflected in their various colours and shades upon the anterior portion of the concavity; another reflection from hence raises images of the external objects near the middle of the vitreous humour, in their natural order and position; these images make due impressions upon the opposite base of the nerve, which are transmitted by it to the brain; thus the sensation is produced, and vision perfected.

This explication of the manner in which vision is accomplished, is corroborated by certain diseases of the organ, in which vision is affected. When an *amaurosis* or *gutta serena* has seized one eye

only, the optic nerve of that eye has been found manifestly altered from its sound state. Dr. Priestley tells us, that he was present, when Mr. Hey examined the brain of a young girl, who had been blind of one eye, and saw that the optic nerve belonging to it was considerably smaller than the other; and he informed him that, on cutting into it, he found it to be much harder, and cinericious.

Besides, no function of the eye, not immediately subservient to vision, is affected by an *amaurosis*. On the contrary, those nerves that go to the choroides are found to retain, in this disease, their natural influence. The iris will contract in a recent *gutta serena* of one eye, if the other remains sound, and is suddenly exposed to a strong light. The sclerotic coat, conjunctiva, and eye-lids, which receive their nerves from the same branches as the choroides, retain their sensibility in this disorder. It is also worthy of observation, that though the pictures are

clear and distinct upon the retina, the diseased organ is incapable of producing vision.

Ever since Scheiner exhibited those beautiful pictures upon the retina, philosophers have supposed the mind, *somehow*, affected by the impressions made upon this membrane; but, mistaking the proper organ, they always found the optical phenomena, and the sensations of vision at variance, and laboured in vain to reconcile them. However, having demonstrated, that neither the retina nor the choroides is the immediate seat of vision; and having restored the optic nerve to that dignified function in the theory, which it naturally possesses in the organ, all the inferior instruments will be found harmoniously cooperating with it, in producing the various phenomena of vision.

It is no longer a question, why the optic nerve has so very large a trunk bestowed upon it; why the *whole* nervous

substance enters the globe *perpendicularly*, and its *circular* base appears within, *destitute* of the choroides. If the medullary substance had not perforated the globe, or if the choroid membrane had covered the base of the nerve; in either case, it is evident, there could have been no impression made by the images in the eye upon the nervous substance; consequently in such a disposition of things there would have been no vision.

But, not only so, we see that while the retina by its transparency answers, throughout its whole extent, the purpose of glass in the production of reflection, this membrane, by covering the base of the nerve, performs the same service for the organ of vision, which the scarfskin does for the immediate organ of feeling. It is well known, when the papillæ pyramidales are deprived of this covering, the least pressure or friction produces exquisite pain. Hence we infer, from analogy, the necessity for the retina co-

vering the base of the nerve or immediate organ of vision, in order to moderate the impression of the rays; for if the nerve were left naked, the least impression made by light upon it would render the sensation intolerable.

However, notwithstanding this surprising coincidence of things in favour of the base of the nerve, as the immediate instrument of vision, those conversant with the subject may have foreseen, what they deem an insuperable objection, which, as soon as it appears, they expect to find me drop, and the whole superstructure I have been raising come to the ground. In short, it is nothing less than the well known fact, demonstrated by the experiment of Mariotte, that the organ is totally insensible to the impression of light, at the very spot that I have fixed upon as the proper seat of vision.

This phenomenon, I confess, appeared for some time a formidable obstacle;

still, I felt a certain confidence powerfully inciting me to perseverance. More disposed to suspect some error in the conclusions drawn by philosophers from the experiment, than to doubt those principles in the structure of the organ, by which the visual image is not only rectified, and other difficult phenomena solved, but upon which I conceived a satisfactory theory of vision might be established, I proceeded, the more anxiously, to seek another solution of this optical difficulty, than that commonly received. In the course of this investigation, I remarked an unaccountable circumstance attending every performance of the famous experiment of the patch upon the wall;—the object *totally disappears*, and its place is constantly supplied by the colour of the ground upon which it is fixed, be that what it may. Now, if the loss of the object opposite the insensible part of the eye, really proceeded from insensibility in the retina, or base of the nerve, whence comes it to pass, that this de-

fect, which ought always to produce a very well defined *dark* spot, should be altogether imperceptible—the spot always assuming the same hue with the wall upon which the object is fixed?

Dr. Porterfield has not suffered this curious phenomenon to escape his notice; and, with his usual ability, endeavours to account for it. After observing, that we are never sensible of this defect in our sight, when both eyes are open; nature having so disposed the optic nerves, both being towards the inside of the optic axis of both eyes; and therefore, what is lost to one eye, is always visible to the other, he adds,

"But we are not only insensible of this defect in our sight, when both eyes are open, but, which is very surprising, in looking at objects of a uniform colour with one eye, the other being shut, we are not sensible of any defect or dark spot, answering to the insensible part of the re-

tina. This becomes very evident, when in the manner above noticed, one loses sight of a round black paper, fastened against a white ground; for no defect or obscurity is to be seen in the place of the black paper, but the ground appears white all over its extent, the same that it does when the black paper is taken away from before it. The reason of which seems to be, that this defect of sensation having been constantly supplied by the other eye, is now supplied by the imagination only."

This explication of the phenomenon appears to me the best, indeed, that can be devised upon the received principles of vision; but altogether hypothetical. Imagination, no doubt, does frequently deceive us, and we are governed by custom in many of the judgments we form in vision; but neither imagination nor custom can have any influence in the production of this phenomenon. On the contrary, we ought the more readily to detect this *unusual* dark spot, whenever one eye is

shut, from being accustomed to see the wall of an uniform colour.

This insensible spot in the organ of vision is, indeed, the hidden rock upon which the most specious theories have been lost. Philosophers have been guilty of a fatal oversight—they have totally mistaken the real cause of this wonderful defect in vision; and, consequently, have left the most beautiful, if not the most important department of physical science enveloped in mystery, and surrounded with difficulties which they confess to be inexplicable. The following optical facts will at once dispel the darkness which has so long hung over this region of philosophy.

If we take a convex line, and place it in the window-shutter of a dark room, and the eye be successively directed towards it, three effects will be produced. When the eye is situated farther from the lens, than the focus of the parallel rays, a very

distinct but diminished landscape, with all the objects inverted, is seen in the lens. On the contrary, if the eye be posited within the focal distance, the objects appear in their natural position, enlarged, but very indistinct. Now, undoubtedly, the medium distance between these two situations, in which the appearances of the objects are so very different, is the true focus of the lens, and the place where the images would be painted upon a sheet of paper interposed. But when the eye is brought to occupy this point, no image whatever, in the lens, impresses the organ; a circular spot, only, is perceived, uniformly tinged with the prevailing colour of the landscape: for instance, if the ground be covered with snow, the lens appears white; if the surrounding scenery consists of verdant fields, woods, &c. the colour exhibited by the lens is green; or if the prospect be upward to the sky, the lens, in this case, assumes an azure hue.

Thus, the cause of that mysterious defect in the field of vision is detected ; the above fact affording a clear demonstration of the effect produced upon the base of the optic nerve, by the famous experiment with the patch upon the wall. Let the wall in this experiment be blue, or green, or any colour whatsoever, the paper is constantly lost in the general hue of the ground upon which it is fixed. But if the loss of the object proceeded from a real insensibility of the nerve, or retina at this place, whatever the colour of the wall might be, a very perceptible *dark* spot would, invariably, be substituted in its stead. So far is this, however, from being the effect produced by the experiment, that, when the wall happens to be white, and even a *black* paper is fixed upon it, no obscurity can be discerned ; the black patch is entirely lost, and an uniform whiteness takes possession of its place.

After this induction of facts, confirmed by the laws of optics, the conclusion can

no longer be doubtful, that the surprising defect in vision, discovered by Mariotte, is neither to be attributed to any insensibility in the retina, nor to the nerve itself, which is the true seat of vision: the phenomenon proceeds solely from the pupil. When the base of the nerve is brought, by distorting the organ, into a straight direction with the pupil and the object, the pencils of rays proceeding from the pupil have their foci upon the base of the nerve; and therefore, agreeably to the phenomenon of the lens above described, that portion of the cornea and humours in the axis of the eye, equal to the diameter of the pupil, is tinged with the colour of the ground upon which the paper is fixed; therefore, while the object, situated in a line with the pupil and base of the nerve, makes no impression upon this, still, the surrounding objects have their forms distinctly painted upon and reflected from the retina: The images, thus formed in the vitreous humour, make the same impressions upon the base

of the nerve as in ordinary vision; and hence a faithful representation is made to the mind of the whole scene, except that portion in the centre corresponding to the dimensions of the pupil.

But the configuration of the concave surface of the eye is such as may induce some suspicion, whether the anterior part be capable of producing perfect images of the objects delineated upon the retina. It may seem doubtful to some, whether such an effect, as that pointed out by us, can be produced by rays reflected from surfaces differently posited, as those of the iris and retina are.

In answer to this, I observe, that as the angle of reflection is always equal to the angle of incidence, whatever be the media through which light passes; and as optical writers have proved, that there is little or no difference between the refractive powers of the humours in the eye; the rays, therefore, that pass from the retina

through the different humours, are returned at the same angle into the vitreous humour, where the images are formed of the objects painted upon the retina. The more serious part of the objection arises from the apparent inequality of surface in the anterior portion of the cavity of the eye, the line of continuity being interrupted by the inner chamber of the aqueous humour, so that the interior surface of the iris being more anteriorly situated than the line of the retina, this disposition of the parts may be supposed to affect the rays in a manner unfavourable to distinct vision. Besides, it may be said, that the iris is not lined with the retina, nor by any other membrane of a similar nature.

Optical writers, however, are by no means determined as to the cause of reflection, nor at what surface of a transparent body, like the retina, light begins to be returned. This is sufficiently evident in the controversy respecting

the retina and the choroides; therefore, till this point be settled, the want of continuity, in the line of the retina and inner surface of the iris, can be no valid objection against a perfect image being formed by reflection, from the anterior concavity of the eye. Nay, this portion of the eye seems more plentifully imbued with the *nigrum pigmentum*, on purpose that the images situated in this direction, opposite to the centre of the nerve, might appear as distinct as possible.

However, in order to see what effect such a disposition of surface would produce upon the reflected image; I took two common watch glasses, the one making the segment of a sphere somewhat smaller than the other, and painted the concave surface of the smaller one black, leaving a small circular space in the centre, similar to the pupil of the eye, transparent; the convex surface of the larger glass I painted black also, and left a larger space in the centre transpa-

rent; so that, when the convex side of this glass was placed within the concavity of the smaller, a part of the blackened surface of this, and the small transparent circle might be visible. Having filled the space left in the cavity of the smaller glass, by the larger spherocity of the other, with water, I cemented the two glasses together, and placed them in the window-shutter of a darkened room, with the concave side inwards. I presented before the concave surface, a small gilt figure: after attentively examining the reflection made by this, seemingly unfavourable disposition of things, I could perceive no difference whatsoever, between the lineaments of the object, and those of the reflected image.

Another objection remains to be noticed. It may be said, that the brilliancy of the choroides in some animals, if not destructive, would at least be highly injurious to vision, if, according to our principles, it were performed by a double

reflection of the image. It might be sufficient, in reply to this, to observe, that we do not profess to treat of vision in any but the human organ. We have already observed, that the choroid membrane of the human eye, is pervaded with a black liquid, and that the inner surface of the iris is still blacker than it, being more plentifully supplied with that liquor; the excess of this pigment is not intended, as generally supposed, so much to stifle the adventitious rays in the eye, as the more effectually to extinguish the light that falls upon its outer surface, and thereby to render the eye a perfect *camera obscura*, as well as to exhibit the images opposite the base of the nerve the more distinctly. However, I am persuaded, that the mechanism of vision is performed nearly in the same manner in the organs of most animals; and that no difference in the colour of the choroides can prevent vision being performed, according to our theory, in the organs of any animal. The powers of concave

reflection, to render the image distinct, is remarkably great. If we take a *meniscus*, or even a common watch glass, and hold its convex side, with a due inclination, close to the flame of a candle, the image of any object, presented to the concave surface, will be very distinctly reflected. Here, then, we have a manifest proof, that the colour of the choroides is not of that vast importance to distinct vision, which some philosophers have supposed; since images may be produced by caustic rays, under circumstances apparently the most unfavourable to reflection, when light is plentifully transmitted, from the most luminous bodies, through the very substance that produce the reflected image.

The dimensions and precise form of the spot in the eye, in which there is no vision, were calculated by Daniel Bernouilli, in the following manner. He placed a piece of money S, fig. 2, upon the floor, and then shutting one of his

eyes, and making a pendulum to swing, so that the extremity of it might be nearly in the line A S, he observed at what point C, it began to be invisible, and where it again emerged into view at A. Raising the pendulum higher and lower, he found other points, H, N, P, G, B, at which it began to be invisible; and others, as M, L, E, A, at which it began to be visible again; and drawing a curve through them, he found that it was elliptical, and with respect to his own eye, the dimensions of it were as follows, S C was 23, A C 10, B D 3, D H 13, and E G 14; so that the centre being at F, the greater axis was to the less as 8 to 9.

From these *data*, the plane on which the figure was drawn, being obliquely situated with respect to the eye, he found that the place in the eye that corresponded to it was a circle, the diameter of which was a seventh part of the diameter of the eye, the centre of it

being 27 parts of the diameter from the point opposite the pupil, a little above the middle. He concludes with observing that, in order that this space, in which there is no vision, may be as small as possible, it was necessary that the nerve should enter the eye perpendicularly, and that both this end, and also its entering the eye at a distance from the axis, are gained by the particular manner in which the two optic nerves unite, and become separate again.

But, according to the structure of the organ and the principles of vision, we have pointed out, it is manifest that the defective spot can have no fixed limits in the eye of any individual. This is decidedly proved, and our theory at the same time remarkably confirmed by an experiment of M. Le Cat. This philosopher, in seeking to improve the experiment of M. Mariotte, substituted a large white board, in place of a dark ground, and observed that at a proper

distance he lost sight of a circular space in the centre of it. He also observed the size of the paper, which was thus concealed from the sight, corresponding to several distances.

Keeping his eye fixed upon the point A, fig. 3, and withdrawing it in the line A P, he carefully measured the sizes and distances of the circles, *a*, *b*, *c*, which disappeared when he was at certain distances from the point A; and upon the whole he found, that to make this second paper disappear, this series of dark circles, formed a dark cone, B, A, C, with an angle of nearly 24 degrees, the upper side A B, being nearly 5 degrees below the horizontal line, and the axis A D, passing through the centres of all the circles, being about 7 degrees below it. These observations furnished him with *data* sufficient to determine the place of the insertion of the optic nerve in any particular eye. By this means he found that in himself, it was nearer to the

axis of the eye, than in M. Mariotte. From the same *data*, he computed the size of this place, in which there is no vision, and found it to be no larger than the head of a small pin, viz. one third or one fourth of a line.

Now, it is evident, that the series of dark circles, produced at different distances by this experiment, is precisely the effect we should have looked for, upon the principles we have laid down. It is well known that the pupil is enlarged in viewing remote, or obscure objects; and that it is contracted when the eye is directed to those that are luminous, or near: hence the smallest circle or obscure spot was observed by Le Cat at the nearest distance from the point A, and the different dark circles, produced by the greater distances, formed the *dark* cone, of which A was the summit.

Besides, it is only upon the principles of our theory that the very great dispa-

rity between the calculations of Bernouilli and Le Cat can be reconciled. The one, as we have seen, has computed the diameter of the defective spot to be one-seventh part of the diameter of the eye; while the other finds its diameter, by his experiment, to be only about one third of a line. How is this difference to be accounted for, since the base of the optic nerve, which philosophers suppose to be the cause of this defect in vision, is actually found at a medium to be one-sixth of an inch in diameter?

Nor can any satisfactory reason be given, on the common hypothesis, for the very great difference just stated, in the admeasurement of the obscure spot in the eye. It will scarcely be said that there really was that physical disproportion between the optic nerves of these two philosophers; and no cause can be pointed out, why the optic nerve of Le Cat should contract to such a degree in making his experiment. But every difficulty va-

nishes, when we view the obscure spot as depending upon the dimensions which the pupil assumes, according as the field of vision is bright, or obscure, and the object more near, or more remote. Hence, M. Le Cat's eye being directed to a point in a large white board, and most probably in a strong light, his pupil was of necessity greatly contracted; and consequently, the obscure spot, as measured by him, was small; on the contrary, the object, in the experiment of Bernouilli, being placed in a more obscure situation, the pupil of his eye was more enlarged; and therefore, the dimensions he took of the spot were proportionally greater than those taken by Le Cat in his experiment.

Thus, having discovered some extraordinary facts in the physiology of the eye, we have solved one of the most perplexing problems in the theory of vision; shewing that the objects of sight are all presented within the organ, and perceived

erect, in the same position with the external or tangible objects. But the evidence for the truth of our theory does not cease here; it will be found accumulating, as we proceed in our investigations into the mechanism of the organ and the phenomena of vision.

THE END.

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