

eyes or are in a very dark place; hence this sensation can be ascribed only to the force of the blow, which sets the optic nerve-fibres in motion as a bright light would do. The same force might make us hear a sound if it affected the ears, or feel pain if it affected some other part of the body. This is also confirmed by the fact that whenever you force your eyes to look at the sun, or at some other very bright light, they retain its impression for a short time afterwards, so that even with your eyes shut you seem to see various colours which change and pass from one to another as they fade away. This can only result from the fact that the optic nerve-fibres have been set in motion with extraordinary force, and cannot come to rest as soon as they usually can. But the agitation remaining in them when the eyes are shut is not great enough to represent the bright light that caused it, and thus it represents the less vivid colours. That these colours change as they fade away shows that their nature consists simply in the diversity of the movement, exactly as I have already suggested. And finally this is evidenced by the frequent appearance of colours in transparent bodies, for it is certain that nothing can cause this except the various ways in which the light-rays are received there. One example is the appearance of a rainbow in the clouds, and a still clearer example is the likeness of a rainbow seen in a piece of glass cut on many sides.

But we must consider in detail what determines the quantity of the light which is seen, i.e. the quantity of the force with which each of the optic nerve-fibres is moved. For it is not always equal to the light which is in the objects, but varies in proportion to their distance and the size of the pupil, and also in proportion to the area at the back of the eye which may be occupied by the rays coming from each point of the object . . . We must also consider that we cannot discriminate the parts of the bodies we are looking at except in so far as they differ somehow in colour; and distinct vision of these colours depends not only on the fact that all the rays coming from each point of the object converge in almost as many different points at the back of the eye, and on the fact that no rays reach the same points from elsewhere . . . but also on the great number of optic nerve-fibres in the area which the image occupies at the back of the eye. For example, if an object is composed of ten thousand parts capable of sending rays to a certain area at the back of the eye in ten thousand different ways, and consequently of making ten thousand colours simultaneously visible, these parts nonetheless will enable the soul to discriminate only at most a thousand colours, if we suppose that in this area there are only a thousand fibres of the optic nerve. Thus ten parts of the object, acting together upon each of the fibres, can move it in just one single way made up of all the ways in which they act, so that the area

occupied by each fibre has to be regarded as if it were only a single point. This is why a field decked out in countless different colours often appears from a distance to be all white or all blue; why, in general, all bodies are seen less distinctly from a distance than close at hand; and finally why the greater the area which we can make the image of a single object occupy at the back of the eye, the more distinctly it can be seen. We shall need to take special note of this fact later on.

As regards position, i.e. the orientation of each part of an object relative to our body, we perceive it by means of our eyes exactly as we do by means of our hands. Our knowledge of it does not depend on any image, nor on any action coming from the object, but solely on the position of the tiny parts of the brain where the nerves originate. For this position changes ever so slightly each time there is a change in the position of the limbs in which the nerves are embedded. Thus it is ordained by nature to enable the soul not only to know the place occupied by each part of the body it animates relative to all the others, but also to shift attention from these places to any of those lying on the straight lines which we can imagine to be drawn from the extremity of each part and extended to infinity. In the same way, when the blind man, of whom we have already spoken so much, turns his hand A towards E [Fig. 8], or again his hand C towards E, the nerves



Fig. 8

embedded in that hand cause a certain change in his brain, and through this change his soul can know not only the place A or C but also all the other places located on the straight line AE or CE; in this way his soul can turn its attention to the objects B and D, and determine the places they occupy without in any way knowing or thinking of those which his hands occupy. Similarly, when our eye or head is turned in some direction, our soul is informed of this by the change in the brain which is caused by the nerves embedded in the muscles used for these movements. . . . You must not, therefore, find it strange that objects can be seen in their true position even though the picture they imprint upon the eye is

inverted. This is just like our blind man's being able to feel, at one and the same time, the object B (to his right) by means of his left hand, and the object D (to his left) by means of his right hand. And as the blind man does not judge a body to be double although he touches it with his two hands, so too, when both our eyes are disposed in the manner required to direct our attention to one and the same place, they need only make us see a single object there, even though a picture of it is formed in each of our eyes.

The seeing of distance depends no more than does the seeing of position upon any images emitted from objects. Instead it depends in the first place on the shape of the body of the eye. For as we have said, for us to see things close to our eyes this shape must be slightly different from the shape which enables us to see things farther away; and as we adjust the shape of the eye according to the distance of objects, we change a certain part of our brain in a manner that is ordained by nature to make our soul perceive this distance. Ordinarily this happens without our reflecting upon it – just as, for example, when we clasp some body with our hand, we adjust our hand to its size and shape and thus feel it by means of our hand without needing to think of these movements. In the second place, we know distance by the relation of the eyes to one another. Our blind man holding the two sticks AE and CE (whose length I assume he does not know) and knowing only the distance between his two hands A and C and the size of the angles ACE and CAE, can tell from this knowledge, as if by a natural geometry, where the point E is. And similarly, when our two eyes A and B are turned towards point X, the length of the line AB and the size of the two angles XAB and XBA enable us to know where the point X is. We can do the same thing also with the aid of only one eye, by changing its position.¹ Thus, if we keep it turned towards X and place it first at point A and immediately afterwards at point B, this will be enough to make our imagination contain the magnitude of the line AC together with that of the two angles XAB and XBA, and thus enable us to perceive the distance from point X. And this is done by a mental act which, though only a very simple act of the imagination, involves a kind of reasoning quite similar to that used by surveyors when they measure inaccessible places by means of two different vantage points. We have yet another way of perceiving distance, namely by the distinctness or indistinctness of the shape seen, together with the strength or weakness of the light. Thus, if we gaze fixedly towards X [Fig. 9], the rays coming from objects 10 and 12 do not converge so exactly upon R or T, at the back of our eye, as they would if

¹ A diagram is omitted here.

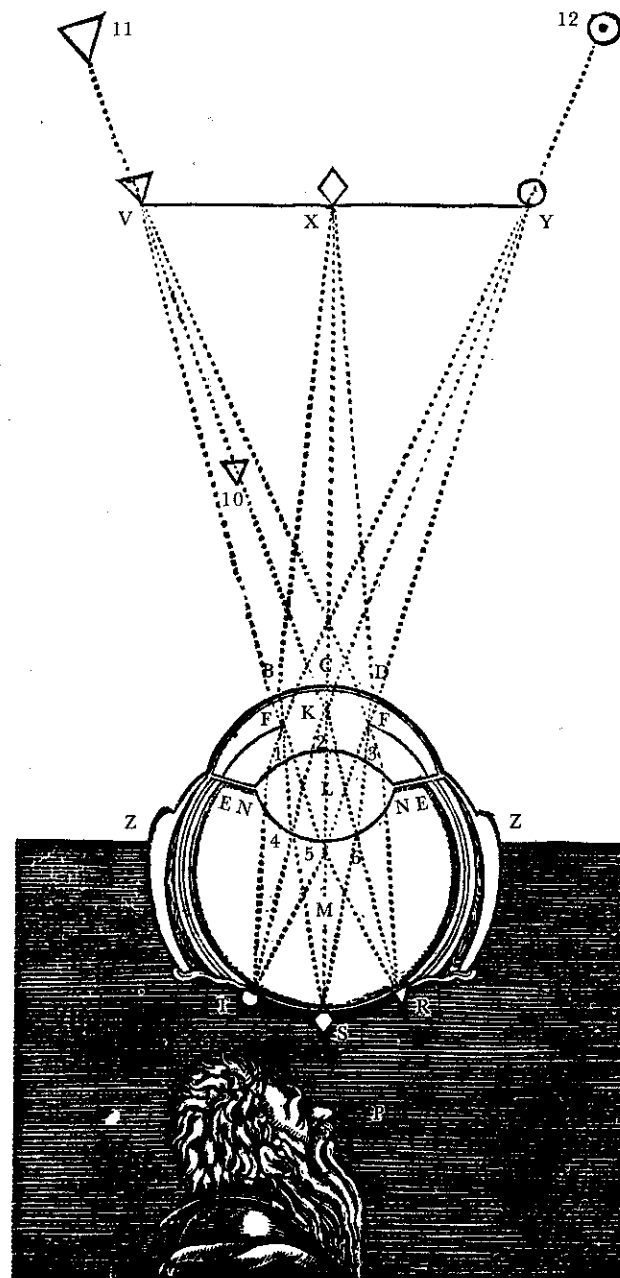


Fig. 9

these objects were at points V and Y. From this we see that they are farther from us, or nearer to us, than X. Then, the light coming from object 10 to our eye is stronger than it would be if that object were near V, and from this we judge it to be nearer; and the light coming from object 12 is weaker than it would be if it were near Y, and so we judge it to be farther away. Finally, we may already have from another source an image of an object's size, or its position, or the distinctness of its shape and its colours, or merely the strength of the light coming from it; and this may enable us to imagine its distance, if not actually to see it. For example, when we observe from afar some body we are used to seeing close at hand, we judge its distance much better than we would if its size were less well known to us. If we are looking at a mountain lit up by sunlight beyond a forest covered in shadow, it is solely the position of the forest that makes us judge it the nearer. And when we look at two ships out at sea, one smaller than the other but proportionately nearer so that they appear equal in size, we can use the difference in their shapes and colours, and in the light they send to us, to judge which is the more distant.

Concerning the manner in which we see the size and shape of objects, I need not say anything in particular since it is wholly included in the way we see the distance and the position of their parts. That is, we judge their size by the knowledge or opinion that we have of their distance, compared with the size of the images they imprint on the back of the eye – and not simply by the size of these images. This is sufficiently obvious from the fact that the images imprinted by objects very close to us are a hundred times bigger than those imprinted by objects ten times farther away, and yet they do not make us see the objects a hundred times larger; instead they make the objects look almost the same size, at least if their distance does not deceive us. It is obvious too that we judge shape by the knowledge or opinion that we have of the position of the various parts of an object, and not by the resemblance of the pictures in our eyes. For these pictures usually contain only ovals and rhombuses when they make us see circles and squares.

But in order that you may have no doubts at all that vision works as I have explained it, I would again have you consider the reasons why it sometimes deceives us. First, it is the soul which sees, and not the eye; and it does not see directly, but only by means of the brain. That is why madmen and those who are asleep often see, or think they see, various objects which are nevertheless not before their eyes: namely, certain vapours disturb their brain and arrange those of its parts normally engaged in vision exactly as they would be if these objects were present. Then, because the impressions which come from outside pass to the

'common' sense by way of the nerves, if the position of these nerves is changed by any unusual cause, this may make us see objects in places other than where they are . . . Again, because we normally judge that the impressions which stimulate our sight come from places towards which we have to look in order to sense them, we may easily be deceived when they happen to come from elsewhere. Thus, those whose eyes are affected by jaundice, or who are looking through yellow glass or shut up in a room where no light enters except through such glass, attribute this colour to all the bodies they look at. And the person inside the dark room which I described earlier attributes to the white body the colours of the objects outside because he directs his sight solely upon that body. And if our eyes see objects through lenses and in mirrors, they judge them to be at points where they are not and to be smaller or larger than they are, or inverted as well as smaller (namely, when they are somewhat distant from the eyes). This occurs because the lenses and mirrors deflect the rays coming from the objects, so that our eyes cannot see the objects distinctly except by making the adjustments necessary for looking towards the points in question.¹ This will readily be known by those who take the trouble to examine the matter. In the same way they will see how far the ancients went wrong in their catoptrics when they tried to determine the location of the images in concave and convex mirrors. It must also be noted that all our methods for recognizing distance are highly unreliable. For the shape of the eye undergoes hardly any perceptible variation when the object is more than four or five feet away, and even when the object is nearer the shape varies so little that no very precise knowledge can be obtained from it. And if one is looking at an object at all far away, there is also hardly any variation in the angles between the line joining the two eyes (or two positions of the same eye) and the lines from the eyes to the object. As a consequence, even our 'common' sense seems incapable of receiving in itself the idea of a distance greater than approximately one or two hundred feet. This can be verified in the case of the moon and the sun. Although they are among the most distant bodies that we can see, and their diameters are to their distances roughly as one to a hundred, they normally appear to us as at most only one or two feet in diameter – although we know very well by reason that they are extremely large and extremely far away. This does not happen because we cannot conceive them as any larger, seeing that we easily conceive towers and mountains which are much larger. It happens, rather, because we cannot conceive them as more than one or two hundred feet away, and consequently their diameters cannot appear to us to be more than one or two feet. The

1 A diagram is omitted here, and the text is slightly condensed.