Since mathematics proved to be a first-class tool by which natural phenomena can be understood, it is obvious that with the growing complexity of these phenomena the mathematical side is becoming more and more complex, hence more abstract, while through this quantitative treatment our knowledge of Nature is really becoming more and more concrete. This contradiction links up with yet another contradiction which exists between science and social organization. It is a paradox that while the scientific worker is more than anybody else responsible for the great advances of civilization, he is at the same time to a great extent divorced from the realities of everyday life.

This contradictory state in science and society forms the background to the efforts of powerful anti-social circles who would encourage the perversion of science into an instrument of destruction. There are scientific men who, perhaps genuinely trying to build for themselves a philosophical framework within which they can work, support these efforts unconsciously. Their books form a useful ally for those who have no interest in science as a progressive factor of social life. As Sir Charles Darwin says: "They excite the wonder of the reader by suggesting to him what extraordinary difficulties there are in the ideas of physics; they are like a conjurer whose tricks seem to us inexplicable". There are others, happily not a majority, who support such moves wholeheartedly. We have only to quote the Nazi-leader Rosenberg about one of these men of science to illustrate the point: "As a thinker Professor Lenard has taught all knowledge is not the same, but souls of alien races produce bodies of knowledge of different spiritual contents".

It is in connexion with these terrible distortions of science that we have to study Newton and his influence on scientific thought, so that this study is not solely of an academic nature. Newton's principles are perhaps best described by Randall, when he says that his most significant contribution lay in the fact that he proved that the ordinary physical laws which hold good on the surface of the earth are valid throughout the solar system. This positive content of Newton's teaching, his objectivism and rationalism, has been transmitted to us by Laplace and Lagrange, by Lavoisier and Dalton, by Planck and Einstein, and in fact has become one of the main features of general scientific thought. The gulf between Lenard and Newton is obvious.

It is in connexion with this gulf that we have to study Newton and his period. There the interdependence of science with the outside world is fairly straightforward. Science and productive forces were in their infancy and their mutual relationship comes out clearly. We can see from it that science has social roots, that the character of scientific progress depends upon social changes. If the main social forces at a definite period are such that men are conscious of their tasks and are striving to solve them, then science progresses too.

What is the task which faces the man of science in this struggle? The answer given by Bernal is: "The task which the scientists have undertaken—the understanding and control of Nature and of man himself—is merely the conscious expression of the task of human society." If we agree with him then we recognize in Newton a great fighter for this aim, and his rationalism and objectivism an essential weapon through the ages which it is our duty to guard.

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THEORIES OF TRICHROMATIC VISION

By PROF. H. HARTRIDGE, F.R.S.

THERE are frequent discussions concerning the rival hypotheses of colour vision, but seldom, if ever, do we see discussed the relative positions of the two rival theories of trichromatic vision. There are two possible plans which present different advantages. These are: (1) That each cone of the retina is able to respond to every one of the three kinds of sensation, red, green and blue; (2) that there are three entirely different kinds of cone, one for the sensation of red, one for the sensation of green, and one for the sensation of blue. The advantages and disadvantages of these two rival hypotheses will now be considered in turn.

The Single-Cone Hypothesis

According to this hypothesis, every cone of the retina is capable of responding to more than one colour sensation. In the fovea centralis every cone can give responses to three colour sensations. In the more peripheral parts of the retina, however, the responses of the cones may be somewhat curtailed to account for the diminution of the colour sense which is found there experimentally.

So far as is known, no single nerve fibre is capable of transmitting more than one kind of nerve impulse. Moreover, each cone of the retina connects with one fibre of the optic nerve and no more. In consequence, every cone must be capable of transmitting up its nerve fibre three different sensations, and this can only be done by variations either in frequency or in the pattern of the nerve impulses which are sent up to the brain. Suppose, for example, that when a cone responds to red rays it sends up its nerve fibre 100 impulses per second, whereas when responding to green it sends up 300 and for blue 1,000. Then, provided that the brain has the necessary structure for recognizing these three different frequencies, recognition of red, green or blue may be satisfactorily explained. When, however, two colour sensations are simultaneously being perceived, there would have to be a transmission of two separate frequencies to the brain. It does not seem easy to picture the simultaneous transmission of two such frequencies. But, on the other hand, alternative bursts of the two frequencies is not improbable; for example, suppose a cone were to be responding to red and green stimuli *simultaneously*, then a short burst of 100 nerve impulses per second would be followed by a short burst of 300 nerve impulses per second, and so on in alternation so long as the stimulus lasted. When white light is falling on the retina and, in consequence, according to the trichromatic theory, all three sensations are being aroused, there would have to be alternations of the three frequencies, each lasting for a short period, and being followed in turn by the remainder.

Now since the type of colour sensation is determined by frequency, it is impossible for intensity of light to be transmitted by any variation in the number of nerve impulses per second sent up the particular nerve fibre. In consequence, it is a corollary of this hypothesis that each cone performs in an all-or-none manner, and that different cones have different thresholds, so that as the intensity of light increases the number of cones responding to that light increases ; thus the active cone population will be small when light intensity is small and will increase to a maximum number as light intensity increases. Sooner or later, as this increase in light intensity continues, the whole of the cone population will have been brought into a state of activity, and further increase of light intensity which takes place will not cause a corresponding increase in the intensity of the sensation received by the brain.

The advantages and disadvantages of this theory may be stated as follows.

Since each cone responds to every colour, visual acuity with coloured light should be exactly equal to visual acuity with white light, and this fits in with experimental observation, any variations which are met with in practice being accounted for without difficulty, by variations in the sharpness of the image projected on the retina by the optical system of the eye. Since the number of active cones increases with the increase of light intensity, an explanation is given for the increase in visual acuity which is observed as light intensity increases. This theory also gives a reasonable explanation of the appreciation of variation of light intensity, since the small increase of light intensity is accompanied by an increase in the number of active cones. This theory gives no explanation of the important observations of Styles and Crawford, who found that the directional effect of the retina differed considerably in detail according as red rays, green rays or blue rays were used for the investigation. It would have been expected, on this theory, that the directional effect would have been the same for all colours, since the colours make use of identically the same cones.

The Triple-Cone Hypothesis

According to this hypothesis, every cone of the retina is capable of responding to one colour sensation only. Thus, in the fovea centralis, there must be three different types of cone, those responding to red, those to green, and those to blue. In the more peripheral parts of the retina, however, one of these types of cone, namely the green, may be reduced in number or may be omitted altogether in order to account for the diminution of the colour sense which is found there experimentally.

According to this hypothesis, the brain receives nerve impulses which inform it of the colours present in the image formed on the retina. It is possible that every one of these cones behaves in an all-or-none manner as was suggested by Hecht, but it is also possible that each of these cones responds in a graded manner, sending impulses along the optic nerves which vary in frequency according to the intensity of light which is falling on the cone in question. This view, which was suggested by me, has been supported experimentally by Hartline and others. This theory fits in admirably with the directional effects found by Styles and Crawford, namely that red light, green light and blue light each has a directional effect which differs from that of the others.

An apparent difficulty is met with in connexion with visual acuity which, at first sight, should have a markedly lower value for light of a single colour than is found for white light, since only about one third the number of cones is being stimulated. This difficulty is, however, avoided when it is remembered that in any random distribution of several different populations there are always places to be found where one population predominates over the others. An excellent example of this is the colour screen of the Lumière photographic plate. In this, there are distributed irregularly three different coloured groups of starch grains, red grains, green grains and blue grains. When such a screen is looked at with the naked eye, red, green and blue dots are clearly visible. On examining these dots with a microscope it is seen that they are not due to isolated starch grains but to quite large groups of grains of almost entirely one colour. Now if the cones of different colour response are distributed irregularly in the same way, then we should expect to find places where red cones predominate and other places where green cones are in excess, and other places again where blue cones are nearly exclusively present. In consequence, when high visual acuity is wanted for any one colour, it is possible to obtain it by causing the image of the object in question to fall on a part of the retina where the cones sensitive to that colour predominate. In the case of yellow light, a spot where there is a predominance of both red and green cones with the almost complete exclusion of blue cones would be most suitable for the purpose.

Evidence of Colour-Blindness

As is well known, colour-blind persons usually fall into one of four categories : (1) protonopes, who are red blind ; (2) deuteronopes, who are green blind ; and (3) tritonopes, who are blue blind ; and (4) anomalous trichromats, who have abnormal colour vision which is, however, less severe than that of any of the three classes mentioned above. The first three types are readily explained on the triple cone hypothesis by supposing that the cone responsible for the missing sensation is either entirely absent or is defective, whereas anomalous vision is explained by a partial defect in one of the sets of cones, usually the green. In the case of the single-cone hypothesis, an explanation has to be sought for on the following lines : either there is deficient in the retina a chemical substance capable of absorbing light of the missing colour, or that the cones themselves are unable to respond to the catalytic products of this chemical substance when it has been broken down by the action of light. Of these two alternative explanations, the first seems to be the more plausible and the easier to picture, although it should be pointed out that there is no histological evidence for the deficiency of one particular type of cone in the retinas of colour-blind persons. In consequence, colour-blindness, which might have been expected to differentiate between these two theories and to eliminate one of them, in actual fact fails to do so.

Conclusions

We have seen that there are two rival mechanisms, both of which will provide trichromatic vision. Of these, the one which most closely fits in with the known facts is that which postulates three different varieties of cone, one corresponding to red light, another to green light, and a third to blue light.