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The new physiology of vision—Chapter XXXVIII. The adaptation of vision to dim light

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The enormous disparity between the illumination available from natural sources by day and by night justifies the terms day-vision and night-vision being used to describe the functioning of our visual organs respectively in these two widely different sets of circumstances. From the investigations set out in the two preceding chapters, it emerged that there is no real difference between day-vision and night-vision except that in the latter case, the red, yellow and blue sectors of the spectrum are not perceived and that only the green, in other words, the part of the spectrum appearing in the wavelength range between 500 and 560 mμ is effective and enables us to perceive illuminated objects. With the aid of three colour-filters, viz., those which transmit only the red, green and blue sectors respectively—excluding in each case the rest of the spectrum—these features of night-vision can be readily demonstrated. The red and the blue filters appear opaque and do not allow of feebly illuminated objects being readily perceived through them. On the other hand, the green filter appears transparent and allows the details of the objects under view to be seen and recognised.

The change-over from day-vision to night-vision can be followed by an observer who views a long narrow slit through which the light of the sky finds entry into a darkened room, while holding a replica diffraction-grating before his eye. The insertion of each colour-filter in turn before the diffraction-grating allows the particular part of the spectrum which it transmits to be seen while the rest is excluded. If such observations are made during the twilight period with the red or the blue filters, a progressive contraction followed by a total extinction is noticeable of the parts of the spectrum which they respectively transmit. But in the case of the green filter, the part of the spectrum transmitted by it remains visible and continues to be seen even after the cessation of twilight and when the light under observation is that of the night-sky.

The differences between day-vision and night-vision can also be demonstrated by observations in a dark room entry of daylight into which is permitted, under control by an iris-diaphragm covering a circular sky-light. The opening of the iris can be set as desired, thereby enabling the illumination of objects within the room to be varied over a great range. Holding a colour filter before his eye, the observer can view the objects in the room at any desired level of illumination. Particularly suitable for such observations is an ophthalmic chart, viz., a white card carrying several rows of printed letters of different sizes. When the opening of the iris is large enough, the chart can be seen and the letters on it can be read through each of the three colour-filters in turn, viz., red, green and blue. But when the iris is closed down sufficiently, the chart ceases to be visible through the red and the blue filters, whereas it can be seen and the printed letters on it can be read using the green filter.

During the period of twilight which intervenes between day and night, human vision adjusts itself automatically to the greatly reduced level of illumination which results from the setting of the sun. If, however, the transition from light to darkness is sudden as for example when an observer moves into a dimly-lighted room from a brightly-lighted exterior, he is at first unable to perceive the faintly illuminated objects inside the room. It is found that an appreciable interval of time is needed for his vision to adjust itself to the lower level of illumination. This change or adjustment of vision to an altered level of illumination is usually referred to as "adaptation". It has been the topic of numerous studies and discussions. We shall in what follows consider the subject in the light of our findings regarding the nature of the differences between day-vision and night-vision. We shall also report some new observational results which enable us to arrive at definite conclusions regarding the nature and origin of the phenomenon.

The period of adaptation: The basic feature of adaptation is that it is progressive with time. It begins when the observer whose vision has fully adjusted itself to a particular level of illumination of the objects around him transfers himself to a different environment which we shall assume, represents a lower level of brightness. The adaptation ends when his vision attains a steady state corresponding to such lower level. The questions which arise and call for our answer are the following. What is the nature of the change which occurs in the visual apparatus and what determines the time required for it?

When considering these questions, we may usefully here recall some well-known facts of experience. The time required for vision to adapt itself to a new set of circumstances is determined both by its initial and final states. It can be stated in a general way that the more widely different they are, the greater is the time needed. If, for example, the first level is in the range of day-light vision and the second in the range of night-vision, the time needed would be quite considerable. If, on the other hand, both of the levels of brightness are in the day-light range, the adaptation would take place much more quickly.

It may also be remarked that the role played by adaptation in the perception of light is specially conspicuous in the case of faintly illuminated objects but is much less evident in the case of those which are brilliantly lighted. For example, an observer entering a dimly-lit room may find some difficulty in recognising objects located in the darker corners. But any metallic objects or other polished surfaces in the same area which reflect light falling on them directly towards his eyes are immediately perceived.

To obtain a fuller insight into the nature and origin of the phenomena of adaptation, we may use the same technique as that described earlier. The observations are conveniently made in a dark room of which the illumination admits of being controlled by opening or closing an iris-diaphragm covering a circular sky-light. The use of an ophthalmic chart as the test-object is also highly advantageous. The observer should place himself at such a distance from the chart that he can read all the letters on it without difficulty if the illumination is adequate. To begin with, the observer's vision may be adapted to bright day-light and the iris-opening of the sky-light reduced to its minimum, so that the illumination of the chart is extremely feeble. The process of accommodation is then naturally slow. The observations may then be repeated in successive stages with the iris more widely open and the shortening of the period of accommodation which results thereby is made evident.

Studies of adaptation in this manner reveal that the progressive increase of the observed brightness of the test-chart during the period of adaptation is accompanied by a simultaneous increase in the visibility of the printed letters on the test-chart. Another remarkable phenomenon is also noticed in these studies. If at any stage during the progress of adaptation, the observer moves forward and comes close to the chart, he notices a great brightening up of its entire area, while simultaneously all the letters on it spring into view and can be read with ease. A similar spectacular increase of visual brightness is exhibited by any feebly illuminated diffusing screen when an observer approaches close to it when his vision is not fully adapted to the low level of brightness.

Another significant observation of interest may also be noted here. Two similar diffusing screens of white plastic material are placed in the path of the light diverging from the sky-light but at different distances from it. For example, one may be twice as far from the light-source as the other. The ratio of their illuminations is then one to four, but their visually observed brightness differs to a far greater extent. At the beginning of the period of adaptation the more distant screen is scarcely visible, while the nearer screen is a conspicuous object. Only at a later stage does the ratio of their visually observed brightness become at all comparable with the ratio of the illumination of two screens.

The nature of adaptation: The observations set forth above leave little room for doubt as to the exact nature of the changes in the visual apparatus that manifest themselves in the phenomena of adaption. What is actually observed is that when an observer remains for a sufficient period in a brightly lighted environment, there is a large reduction in his power to perceive feeble light, but that on the other hand the ability to perceive bright light remains more or less unimpaired. The only explanation of this phenomenon that could be suggested and that could be reconciled with the facts of observation set forth above is that the individual receptors of light in the retina exhibit an effect in the nature of fatigue as the result of a continued functioning in bright light for a long period of time. Such fatigue results in their inability to receive and transmit very weak impulses to the cerebral centres, while on the other hand their ability to receive and transmit more powerful impulses is not seriously impaired. Prolonged rest in darkness may be expected to abolish this fatigue and enable feeble illumination to be perceived to the same extent and in the same manner as bright light.