Light and Sight.

By Sir JOHN PARSONS, F.R.S.

AN opportunity for exemplifying one aspect of the relationship between physics and physiology, namely, that of the physical stimulus to a sense organ and the physiological response, was afforded by the Tyndall Lectures upon "Light and Sight," delivered by me at the Royal Institution on Nov. 1, 8, and 15. John Tyndall, in addition to being a physicist, drifted into biology, and by his experiments on spontaneous generation may be regarded as a pioneer in bacteriology. He was also a philosopher. He himself expressed his indebtedness to three men—Carlyle, Emerson, and Fichte. "These three unscientific men," he said, "made me a practical scientific worker." His philosophy led him strongly to support the pioneers of the evolutionary theory—Darwin and Wallace, Herbert Spencer and Huxley. Specially strongly did he support that canon of scientific discipline which was so ably enunciated by Huxley and rather unfortunately branded by him with the contentious name, agnosticism. Here Tyndall was overshadowed by his great contemporaries, and the immense effect of his Belfast address is liable to be overlooked by the historians of science.

The essence of the agnostic creed was a judicial suspicion of authority and the cultivation of suspension of judgment in regard to matters which are not yet susceptible of rigorous scientific proof. It cannot be doubted that the rise of the theory of relativity and the deductions therefrom have led to a weakening of scientific discipline and a too facile acceptance of plausible speculations. A reversion to the stricter canon of Tyndall and Huxley would be beneficial to all branches of science, and not least to physics, where hypotheses as to atomic structure, the constitution and life history of the stars, etc., are asseverated as facts with all the adamant validity of the laws of the Medes and Persians. As Sir Arthur Keith has recently said, "The unfortunate position is that in this world there are men who will not be satisfied with not knowing"—an ambiguous remark which, however, as meant, embodies a great truth.

Our consciousness of the world around us is derived from impressions conveyed to our sense organs, of which the most important for us are the organs of vision. The integrated results of our sensory impressions are perceptions, which thus originate in the absorption of energy in various forms by the sense organs and its transformation into physiological impulses which are conveyed by sensory nerves to the brain.

In considering the radiant energy emitted by sources of light, such as the sun and artificial illuminants, and its distribution throughout their spectra, it is interesting to note that the human eye has become specially adapted to sunlight, as shown by the fact that the brightest part of the spectrum, as seen by the light-adapted eye, coincides more or less accurately with the summit of the curve of radiant energy.

As Helmholtz long ago pointed out, the eye shows many defects as an optical instrument. The refracting surfaces are not accurately spherical; they are not accurately centred on the optic axis; they are not completely homogeneous and therefore give rise to irregular astigmatism, or completely transparent; the cornea and lens are not free from spherical or from chromatic aberration. Hence Helmholtz's oft-repeated dictum that if an optician delivered so faulty an instrument it would be justifiable to return it to the maker. Even Homer sometimes nods, and it is regrettable that Helmholtz should have uttered so unjust a sarcasm. For the true criterion of the eye as an organ of vision is its biological utility, *i.e.* its capacity to fulfil its manifold functions in the interests of the individual and ultimately of the race. An instrument approximately a sphere of 11 mm. radius, which combines the advantages of being a camera with automatic adjustment from infinity to a distance of 3 or 4 inches and unparalleled range of sensitivity, an efficient photometer, colorimeter, kaleidoscope, stereoscope, and range-finder cannot be regarded as inefficient.

The criterion of visual acuity is the capacity to distinguish two points of light as separate, *i.e.* the *minimum separabile*. This depends on the resolving power of the eye and the fineness of grain of the screen upon which the image is formed, *i.e.* the neuroepithelium of the retina. Experimental observations showing a minimum visual angle of 40" of arc coincide well with the mean diameter of the foveal cones, 3μ . But contour discrimination, with a minimum visual angle of 10", or even binocularly of 2" (Andersen and Weymouth), is much less easy to explain. As shown by Hartridge, the key to the problem is found in the *difference* of illumination which is perceptible to cone vision. It is a striking example of the law that all perception is perception of change.

It can be safely stated that there is no form of sensory discrimination which is so highly developed as that of contours; and it is noteworthy that it has been employed empirically by physicists in the vernier. When the vernier method is inapplicable, as in photometry, the error of experiment is greatly increased. It is well for physicists to remember that the accuracy of their measurements depends upon a biological foundation (see NATURE, 110, 824; 1922).

The bearing of these facts on the physiology and psychology of reading elicits many interesting conclusions. The defects of the optical apparatus lead to diffusion images, and cause irradiation, whereby the image of a dark object is encroached upon by the surrounding white. Irradiation in print is largely counteracted by the use of serifs and by careful design of the letters and spaces. Thus, the interspace between round letters like *o* and *e* should be less than that between square letters. Moreover, the significant parts of letters are usually

in the upper half, so that a line of print can be easily read if the lower halves of the letters are covered, but is illegible if the upper halves are covered.

The eye is not only automatically adjustable to distances, but also its sensitivity is automatically adjusted to the amount of light entering it. The sensitivity of the retina increases enormously in dark adaptation, and scotopic or twilight vision differs in many respects from photopic vision. Evidence derived from physiological and pathological observations supports the view that the rods are responsible for scotopic, the cones chiefly for photopic vision. This is the so-called duplicity theory. Thus, the rod-free area of the macula is night-blind, as was long ago discovered by astronomers, and it is generally held that the Purkinje phenomenon is absent at the fovea. Further, the rate at which the eyes become adapted to dim light varies somewhat in normal people, and there are diseased conditions in which it is very slow or almost absent. Such people are night-blind. They are practically incapacitated in dull lights, and cannot get about after dark. In one rare group the eyes appear to be otherwise normal and the disease is transmitted from one generation to another. The most famous and most extensive pedigree of any diseased condition is that of some congenitally night-blind people in the Montpellier district in the south of France. The pedigree was started by Cunier in 1838 and brought up-to-date in 1907 by Nettleship. It consists of ten generations of 2121 persons, 135 of whom were night-blind. Much commoner is the night-blindness associated with the disease of the retina called retinitis pigmentosa.

An interesting antithesis to night-blindness is found in the rare cases of congenital total colour-blindness. For the normal sighted the colourless grey spectrum of scotopic vision becomes suffused with all the colours of the rainbow as the intensity of the light is increased. For the totally colour-

blind, although the brightness increases under these conditions, no colours are seen. Moreover, there is no shift of the maximum brightness from the green to the yellow region of the spectrum, such as occurs in the normal.

On the duplicity theory, the congenital night-blind may be regarded as having only cone vision, and the totally colour-blind only rod vision. There are, however, difficulties in accepting this simple explanation.

The discovery of the visual purple indicates forcibly that the first stage in the energetics of the retina is photo-chemical. It is associated with electrical changes of great complexity; and whereas Adrian has shown that the electrical changes in the optic nerve are in all respects like those in an ordinary nerve under excitation, the correlation of these changes with those of the more complex retina has yet to be elucidated.

Stimulation of the retina by an instantaneous flash of light elicits two facts—the persistence of the visual impression for an appreciable time beyond that of stimulation, and the recurrence of vision. The latter is due to the pulsatile nature of the sensory response. It accounts for such peculiar phenomena as ‘Bidwell’s ghost,’ Charpentier’s bands, and so on. One of the most striking phenomena is the production of a colour sensation by pure black and white stimulation, as in Benham’s top; and this has recently been partially explained by Piéron on the same principle.

The relations of these scientific observations on light and sight to such practical problems as the illuminations of rooms, factories, art galleries, etc., and the hygiene of vision in relation to flickering lights, the cinema, etc., is full of interest, but also often very obscure. The investigation of such problems is the chief work of the Physiology of Vision Committee of the Medical Research Council.

The Second Danish-Icelandic Expedition to Iceland, 1927.

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OUR knowledge of the interior of Iceland is of quite recent date and still in part very incomplete, even to the point that there are districts which may be said to be utterly unknown to science. This applies both to topography and to geographical and geological conditions. The reason is that it is very difficult to push into the highlands of the interior, because different difficulties, each of which requires to be met by a special technique on the part of the traveller, combine to present obstacles to his passage as well as to his closer scientific investigation of the country.

In a purely practical way the coast districts have been known ever since the country was first inhabited, that is, for about a thousand years, and similarly certain tracks through the inner highlands, which one may suppose were considerably better known seven or eight hundred years ago than they were in the eighteenth and nineteenth centuries. Meanwhile, the last fifty years have made great

changes in our knowledge of this region, inasmuch as a great advance has been made in the scientific investigation of the highlands, and at the same time in a practical knowledge of the country. This advance is due to a considerable number of able and energetic men of science and travellers, among whom one may name Winkler (1858), Preyer and Zirkel (1860), Keilhack (1883), Watts’s various expeditions in the ‘seventies, and Biziker (1900). Above all, one must mention the great work carried out by the distinguished Icelandic investigator, Thorvaldur Thoroddsen, who in the last two decades of the nineteenth century travelled over a very great extent both of the highlands and of the coast districts, and published numerous papers on the geography and geology of Iceland. We further owe to Thoroddsen a number of excellent handbooks which are among the most important aids in Icelandic exploration. Since 1898, when Thoroddsen’s journeys ended, the work has been continued by