COLOUR VISION, 1868 and 1948

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"THE vast literature on colour vision consists almost entirely of papers written in support of some particular theory. It is peculiarly difficult to obtain a general and unbiased view of the subject, which demands a not inconsiderable knowledge of such diverse subjects as physics, physiology and psychology. I have here endeavoured to separate the best established facts of colour vision from the theories, and have then discussed the chief theories in the light of these facts."

In these words Sir John Parsons opened the Preface to his book "An Introduction to the Study of Colour Vision," and no more fitting comment could be made on the troubles that beset a student of colour vision. In a tribute such as this, it would be out of place to flog the merits of this or that theory, but it is intriguing to look back and compare the facts and theories of 1868 with those of the present day.

The year 1868 does not itself appear to be notable for any major scientific contribution to colour vision, but the period seems largely to have been dominated by the outlook of Helmholtz and Clerk Maxwell. That, of course, is equivalent to saying that the Young-Helmholtz theory was widely accepted, as a result of the colour mixing experiments described a few years earlier by both Helmholtz and Maxwell, and supported by the principles governing colour equations, as enunciated by Grassmann. Indeed, the Maxwell colour triangle had been described and the geometry of the triangle on the "centre of gravity" principle had been developed, while Maxwell had also given a very apt account of a three-dimensional method of specifying a colour in terms which would be very acceptable to many workers to-day.

The undue prominence apparently given to colour mixture data at that time was no doubt due to the fact that it was the chief sensory phenomenon on which fairly reliable measurements could be recorded. Three important methods of colour matching were available, namely the Helmholtz polarisation spectrometer in which the intensities of the matching stimuli were controlled by polarisation prisms, Maxwell's colour box in which slits of variable width in a spectrum provided the controls, and the colour top, in which the areas of each colour exposed on the top could be varied.

The physical energies of the red, green and blue lights used as

the matching stimuli were not known, but this was of no consequence in the development of the Maxwell triangle, since the units of the three lights were arbitrarily chosen to equalise the quantities of the three required in a match of a white light. It is rather interesting to realise that this basis for the units was almost forced on Maxwell by the lack of any other physical means of recording the intensities of the lights, and yet so effective has the system proved that it is firmly established at the present day and is embodied in the international C.I.E. system of colour specification.

This same difficulty of how to measure physical energies no doubt accounted for the absence of any measurements of the luminosity curve of the spectrum. Fraunhofer, it is true, had in 1817 published measurements on the brightness of different parts of the spectrum, but these results do not appear to have been followed up for many decades, while even at the end of the century, data were still being reported relative to the energy distribution associated with some particular light source rather than for a spectrum of known energy composition. Hence in 1868 the problem of actually sub-dividing the luminosity curve into three component parts had evidently not arisen.

Nevertheless, this was perhaps the hey-day of the trichromatic theory, when there was every promise that the main phenomena of colour vision would fit neatly into a simple framework of three independent receptor processes in the retina and three response paths from retina to brain, while the sketchy physiology of the time was simply inadequate to put the theory to a critical test. The theory, too, was well adapted to the mechanistic certainty characteristic of the Victorian era, before the subtleties of quanta, probabilities and statistics had invaded the scene.

Even so, the trichomatists were not unchallenged and in 1865, for example, Aubert's book, "*Physiologie der Netzhaut*," helped to restore the balance by the emphasis placed on adaptation and contrast phenomena, and by his insistence on four fundamental colour qualities—red, yellow, green and blue. This theme, of course, was later to be taken up by Hering, and Aubert's work may be regarded as the forerunner of the Hering school of thought. The failure on the part of the trichomatists to dissociate in their arguments the number of receptor processes from the number of distinct sensation qualities has been one of the most persistent causes of misunderstanding between the protagonists of the different theories.

What of visual physiology in 1868? Although the reddish coloration of the retina due to visual purple had been noted in the 1850s, the actual discovery of visual purple by Boll dates from

1876, with Kuhne's more exhaustive studies following during the next few years. On the anatomical side, while Treviranus had described the rods and cones in the retina in 1835, and some 20 years later H. Müller proved that the rod-cone layer was the photo-receptive layer, it was not until the 1880s that Ramon y Cajal commenced the work that was to lay the foundations of our present detailed knowledge of the retinal structures. Still more elementary in 1868 was the knowledge of the electrical response of the retina, for the first electro-retinogram had only recently been recorded by Holmgren in 1865.

Perhaps the state of colour vision knowledge at that time can best be described as lop-sided and fragmentary, a condition naturally fertile to the conflict of ideas that was so soon to develop. The cut and thrust of argument and experiment which we associate with the end of the century acquired a tempo that must have been exhausting as well as invigorating and without our Parsons' "Colour Vision" we might well despair of ever seeing the period in perspective.

We know that an extraordinary interest in defective colour vision was soon to be shown and extensive experimental data were accumulated. With the rise of the Hering school, emphasis was switched to adaptation effects and the subjective appearance of colours, but in view of the lack of information even now about the photo-chemistry of the cones, attempts to explain these effects in terms of anabolic and katobolic processes were obviously premature.

By 1924, Parsons could write ("Colour Vision," 2nd edition, p. 205): "If we rapidly survey the sections of Part I (dealing with The Chief Facts of Normal Colour Vision) we shall find that the quantitative relationships are best established for luminosity and colour with the photopic fovea and for luminosity with the achromatic eye. When we consider peripheral vision, temporal and areal effects, both for photopic and scotopic vision, the quantitative relations are far less well established. The same grouping applies to Part II (dealing with the Chief Facts of Colour Blindness)."

This, surely, could also be written in 1948. Tangible and important advances have, of course, been made in the purely physiological aspects of the histology, photo-chemistry and electro-physiology of the retina, but to what major advances can we point on the visual and subjective side? Our experimental techniques are certainly better—we have better light sources, we can measure the physical energy of our light stimulus, we have improved optical equipment such as spectrophotometers, colorimeters, colour filters, photometer wedges and filters—so that we can now control and specify the conditions of our experiments with

greater precision. This has led to more accurate colour and luminosity measurements resulting in the international adoption of standard luminosity and colour mixture data, which have in turn enabled the observing conditions of an experiment to be defined more definitely.

These can be claimed as advances, but they are technological rather than scientific, and as contributions to colour vision theory do not take us much farther than the Helmholtz-Maxwell era. Perhaps this is inevitable; perhaps we must resign ourselves to still further delay until we have more exact and direct information about the physiological processes in the retina.

In another sense, too, we have advanced. As the late Professor Selig Hecht said at the Colour Vision Conference at Cambridge in 1947, we are at last beginning to grow up. We are acquiring a confidence in our measurements that was lacking before. We no longer regard points which lie off a smooth curve as necessarily erroneous observations, but are prepared to draw curves with humps in them. We no longer regard the scatter in our observations as an annoying inaccuracy, but rather as a significant measure of discrimination ability which, when analysed statistically, may lead to useful information about the processes of discrimination.

We have a clearer idea, too, of the nature and intricacies of the subject. Mostly we remember to distinguish between the physical stimulus, the physiological reaction and the psychological sensation. Our concepts are sounder; we recognise the need to describe the conditions of stimulation and to control the observer's state of adaptation. All this is at last becoming instinctive and in this respect we credit ourselves with a superiority over our predecessors.

Yet how much of the credit should go to Sir John Parsons! In his writings and conversation he has continually reminded us that our outlook must be broad. To the physicist he has had some hard things to say. Thus in his Thomas Young Oration (*Trans. Optical Soc.*, Vol. XXXII, p. 165, 1930-31): "Physicists cannot afford to ignore the teaching of physiologists. Physicists have been and are often now supercilious of the relatively inexact sciences, such as physiology, medicine and psychology. Let them ponder upon this indisputable fact—that all their measurements are founded upon their powers of sensory discrimination. They have been let off very lightly for their comparative neglect of this fundamental fact. It is a sheer piece of luck that they quite empirically hit upon the finest of all forms of sensory discrimination, *viz.*, contour discrimination, and applied it in the form of the vernier to their instruments."

However, as the physicist is recovering from this admonishment,

he is delighted to read a few paragraphs later: "I have already criticised the failure of physicists to pay sufficient attention to physiology. *Per contra*, I much doubt if there are many physiologists who really understand the remarkable juggling feats of König, Helmholtz, Abney and other physicists."

These are pretty sharp stimuli, and if we would do honour to their author, we cannot do better than respond as he would wish. There is no very obvious sign in 1948 that all the remaining colour vision problems are about to be solved; our aim must be to fill the gaps with experiment rather than theory, and to make sure that our experiments are designed on sound principles such as Sir John Parsons would approve.

THE FIRST IRISH OCULAR PATHOLOGIST

Arthur Jacob—(1790-1874)

BY

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It is fitting that Arthur Jacob, the first Irish ocular pathologist, be recalled in this number of the Journal.

Although I can find no evidence in Jacob's biographies, or in his own numerous papers, that he ever actually practised any branch of medicine other than ophthalmology, he, like most of the medical giants of his age, was far from being satisfied by a mere speciality. He founded two ophthalmic hospitals, and took a leading part with others in founding both a medical school and a general hospital. He was joint founder and sole editor for 21 years of a medical journal. For 41 years he was a Professor of Anatomy and Physiology. Scientifically, he will be remembered as the first to describe the nervous layer of the retina (*membrana Jacobi*) and the rodent ulcer of the lids (Jacob's ulcer), and in the field of medical politics as a tireless fighter for medical reform, a dauntless champion of doctors' rights and a fearless opponent to all forms of quackery.

The details of his life need not detain us. Born in 1790 near the town of Maryborough (now Portlouis), in Queens County (now Leix), the son of Dr. John Jacob, surgeon to the Queens County Infirmary, and grandson of Dr. Michael Jacob (Ballinakill), he came of a stock that had been in the midlands of Ireland for some centuries. The family was English and Jacob appears to have been a direct descendant of the Jacobs who had lived in Kent in the