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The trichromatic hypothesis

SIR C V RAMAN

"My design in this book is not to explain the properties of light by hypotheses, but to propose and prove them by reason and experiments." So reads the opening sentence of Newton's classical work on optics in the first book of which the foundations of the theory of colour were firmly laid and a bridge thus built between the physics and the physiology of vision. Precisely what Newton had in mind when he made the reference to hypotheses contained in this sentence may be inferred from the following passage which appears towards the end of his book. "As in mathematics so in natural philosophy, the investigation of difficult things by the method of analysis ought ever to precede the method of composition. This analysis consists in making experiments and observations, and in drawing general conclusions from them by induction and admitting of no objection against the conclusions but such as are taken from experiments, or other certain truths. For hypotheses are not to be regarded in experimental philosophy." From these remarks it is clear that the hypotheses which Newton had in mind are assumptions of an arbitrary character not based on well established facts of observation.

Newton's aversion to hypotheses was not unjustified. For, there is a danger in adopting hypotheses when no real knowledge is available of the facts of the subject. A species of self-deception then becomes possible leading one to beliefs which are either wholly unjustified or else are only half-truths. Further, they are liable to make one blind to facts which come to light later and which are themselves a patent contradiction of the hypothetical assumptions. These remarks are made here with special reference to the hypothesis originally put forward by Thomas Young and now known and referred to generally as the trichromatic theory of vision. That the theory is based on *ad hoc* assumptions and not on any well-established facts will be made clear later on. It will suffice here to mention that Young himself thought that the three primary sensations were those of red, yellow and blue, and later changed over to red, green and violet as a better choice. But before commenting any further on Young's hypothesis and its subsequent history, it appears desirable in the first instance to state the actual facts of the subject.

We may usefully begin by quoting in Newton's own words the conclusions which he arrived at as the result of his studies on colour. In characteristic fashion, he summed them up in two "definitions" which are reproduced below verbatim:

Definition VII: *The Light whose Rays are all alike Refrangible, I call Simple, Homogeneal and Similar; and that whose Rays are some more Refrangible than others. I call Compound, Heterogeneal and Dissimilar.* The former Light I call Homogeneal, not because I would affirm it so in all respects, but because the Rays which agree in Refrangibility, agree at least in all those their other Properties which I consider in the following Discourse.

Definition VIII: *The Colours of Homogeneal Lights, I call Primary, Homo geneal and Simple; and those of Heterogeneal Lights, Heterogeneal and Compound.* For these are always compounded of the colours of Homogeneal Lights; as will appear in the following Discourse.

Newton's ideas are very clearly expressed in the foregoing extracts. In the first place, he recognised that the physically simplest forms of light—which we would describe today as radiations manifesting themselves as single sharp lines in the spectrum—are also the exciters of the primary or simple physiological sensations which are the pure colours of the spectrum. Newton also recognised that the sensations excited by polychromatic light are compounded of these primary sensations and are, therefore, necessarily of a more complex character.

That the sensations excited by monochromatic light are the primary physiological sensations and that these are quite as numerous as the colours which can be perceived as distinct from each other in a pure spectrum is established by various facts of observation. On no other basis can a reasonable explanation be offered for the fact that our visual faculties enable us to distinguish between the colour of closely adjacent regions in the spectrum. Indeed, in some parts of the spectrum, a difference of as little as 10 Å in the wavelength of the light suffices to produce an observable difference in colour. Then again, if monochromatic light be admixed with white light, we can still perceive and recognise the colour in such admixture and what is perhaps even more significant is that our ability to discriminate between the colours of closely adjacent regions of the spectrum is not altered appreciably even when they are both admixed with substantial proportions of white light.

Light, according to Newton's ideas expounded in the third book of his treatise, is of a corpuscular nature. In other words, it consists of small bodies emitted by the source of light, their sizes being different for the differently coloured rays of the spectrum and altering continuously as we pass from one end of the visible spectrum to the other. On this basis, the existence of a definite relationship between the refrangibility of light and its observed colour is only to be expected. To quote Newton's own words, "nothing more is requisite for producing all the variety of colours, and degrees of refrangibility, than that the Rays of Light be Bodies of different Sizes". It was inevitable, therefore, that Newton should recognize the colours of the spectrum as the primary, homogeneous, and simple colours and the colours of lights of different sorts mixed with each other as heterogeneal and compound.

The corpuscular view of the nature of light favoured by Newton fell into disrepute during the nineteenth century. It was no accident that the physicists who were associated with the development of the wave-theory of light thought fit to reject Newton's conclusions regarding colour and its perception and attempted to replace them by other assumptions of a hypothetical nature. They could not have foreseen that all such attempts were foredoomed to failure and that the corpuscular concept of light would emerge once again, triumphantly vindicated. The different sizes of the particles of light contemplated by Newton are replaced by the different magnitudes of the energy-quanta which they represent.

It is a fact of observation that the eye can discern some 150 or more different hues in the spectrum. Rejecting this as an inexplicable achievement of our faculty of vision, Young postulated that there are only three different "principal" colours and that the rest are only derivatives. The question then arose, which three colours should be chosen as the "principals". Young's first choice was that of the colours red, yellow and blue. Later, he discarded these and adopted red, green and violet as his favourites. He then drew an equilateral triangle having these three colours at the vertices, white at the centre and the other spectral colours as points lying on its two sides.

Young's triangle of colours was just pure phantasy. For, later studies have shown in the most conclusive manner that the pure colours of the spectrum stand in a category by themselves and that they cannot be equated to the result of any superposition of other colours. This fact alone is sufficient to prove the correctness of Newton's analysis of the subject of colour and is a shattering blow to the ideas underlying the trichromatic hypothesis. But, as has been remarked earlier, believers in *ad hoc* hypotheses do not readily admit defeat when confronted by the discovery of new facts. They assiduously seek to find ways of escape from the consequences of such discoveries.

One of the several ways in which it has been sought to bolster up a belief in the validity of the trichromatic theory, instead of allowing it to join the limbo of discarded hypotheses, has been to suggest that all observable colours could be represented as equivalent to the result of superposing three suitably chosen colours in suitably chosen proportions. The equivalence is represented in the form of an algebraic equation, quantities being introduced therein known respectively as trichromatic coefficients and tristimulus values, suggestive of a mysterious power and significance for the number three in colour theory. Geometric representations have also been devised in which colours were represented as points in a system of trilinear co-ordinates. A critical examination of these representations of colour shows, however, that they are devoid of any real physical significance. This becomes evident when it is remarked that in the XYZ system which is generally adopted for the geometric representation of colour, the vertices X, Y, Z of the triangle do not represent any real physical colours, the entire triangle lying outside the area in which the points representing actual colours lie. Indeed, these representations mean little more than that any actually observed colour resembles the result of superposing an achromatic sensation upon a recognisable colour with a saturated hue, a fact which was known to and stated quite clearly by Newton in his treatise.

The subject of the sensations excited on our visual organs by polychromatic radiations is one of considerable interest and importance. One has only to recall the vast number of possibilities included in the words "polychromatic radiation" to appreciate that only observational data obtained on the widest possible basis and by methods not influenced by bias of any sort could be expected to reveal the real facts of the subject. So far from the trichromatic theory of vision having been of any real assistance towards the understanding of this difficult and complex field, it has only served to introduce error and confusion and stood in the way of any real advances in knowledge.