Letters

Quantum Phenomena in Biology

C. Reid (*1*) discusses (among other topics) some recent trends in research on the visual process. In so doing, he keeps the action of rod and cone cells separate, referring to the former as a "monochromatic mechanism" and to the latter as a "trichromatic color-vision process." Wald (*2*) presented a very interesting set of deductions and speculations on the action of rhodopsin and the effect of its bleaching on rod *and* cone activity. The hypothesized structure of both rods and cones is one of compartments containing rhodopsin molecules. The number of compartments per cell can vary, as can the number of rhodopsin molecules per compartment. Sensitivity of a cell is a direct function of the number of compartments and of the amount of rhodopsin per compartment: the more rhodopsin, the higher the probability that that cell will absorb a quantum of light. Several deductions follow from a statistical theory based upon Wald's suggestions—for example, light and dark adaptation phenomena and scotopic and photopic luminosity curves. One new prediction was derived and tested with critical flicker fusion (*3*). The data showed a closer approximation to Wald's conceptualizations than to Crozier's (*4*).

With monochromatic light sources, similar predictions would be difficult to make. Again, some well-grounded speculations may be cited (*5*). First, it is interesting to note that Reid talks of a "trichromatic color-vision process in the cone cells" and observes that "none of the three mammalian cone-cell pigments (these have not yet been isolated) is rhodopsin." Young and Helmholtz started the trichromatic theories; Hering and Ladd-Franklin opposed them; Granit and Hartridge presented ample evidence that perhaps 7- or 11-color theories may be more correct (see *6*).

Trichromatic theories are still in vogue today, due to the existence of three physical primaries, or to our language habits, or to inertia, or to some combination of these, despite the evidence. From the work of Granit and Hartridge it is only one more step to a statistical theory of color vision. This is the step Shaw has taken. One could return to Wald from Shaw's theory and conceptualize compartments containing varying amounts of chlorophyll, xanthophyll, carotene, and other optically active substances. These varying amounts would be distributed normally (like rhodopsin) among cones and cone compartments, so that any given cone might contain close to the mean value of chlorophyll; or it might contain an amount of chlorophyll three standard deviations above the mean and would therefore be a "green cone"; or it might contain a large amount of xanthophyll and be a "yellow cone." Such a theory would seem to be more promising and closer to the content of Reid's paper than a trichromatic theory. I leave the details of such a theory to someone better versed in photochemistry than I.

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References and Notes

1. C. Reid, *Science* **131**, 1078 (1960).
2. G. Wald, *ibid.* **119**, 887 (1954).
3. H. F. Gallup, *NAMC-ACEL-341* (16 Aug. 1957).
4. W. J. Crozier, *Proc. Natl. Acad. Sci. U.S.* **28**, 65 (1940).
5. W. A. Shaw, *Psychol. Rev.* **63**, 228 (1956).
6. S. H. Bartley, "The psychophysiology of vision," in S. S. Stevens, *Handbook of Experimental Psychology* (Wiley, New York, 1951), chap. 24.

I believe that Gallup's interesting ideas about cone vision cannot be reconciled with the experimental facts. For instance, Rushton [*Proc. Natl. Acad. Sci. U.S.* **45**, 114 (1959)] has shown, by examination of the reflection spectrum of the fovea centralis of red-blind (protanopic) individuals, the absence of a pigment throughout the red region of the spectrum. Because of the widespread occurrence of this phenomenon, it seems very unlikely that more than one pigment is missing, and consequently this single pigment must be effective over a considerable region of the spectrum. A second pigment, effective in the blue-green region, was also identified by Rushton, and it seems quite reasonable to conclude that a third must exist, covering the blue part of the spectrum. There is nothing in Rushton's spectra to indicate the presence of rhodopsin in the cone cells.

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Pseudo Science and Censorship

With reference to the editorial "Rebutting the preposterous" [*Science* **131**, 1163 (22 Apr. 1960)], two important questions are implied therein.

1) Who is to judge that grey area, between "accepted science" and pseudo or crackpot science? For it is here that new discoveries arise, and here originate the "breakthroughs" that all are so eagerly seeking. I remember well when the expanding universe and virus as a causative agent in cancer were two ideas believed to have very little merit —then pseudoscientific, if you will.