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Refractory compartments and the quantum efficiency of rods.

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The sensitivity of rod-dependent vision is affected by light to a much greater extent than can be accounted for directly by the bleaching of visual purple. It has been suggested by Wald (1954) that this is because the bleaching of a single molecule of rhodopsin makes the whole of a compartment refractory, and thus renders inactive (for excitation) all the rhodopsin held in the same compartment as the molecule bleached. Wald suggested that the compartments might be the disk-shaped lamellae which make up the rod outer segments, but they might be larger or smaller than this.

On this hypothesis the ratio of the threshold measured at the start of dark-adaptation to the final threshold indicates the fraction of the compartments which are left non-refractory by a given degree of light-adaptation. If this is correct, the same, or a smaller, fraction will be excitable during exposure to the light-adapting field, and hence the efficiency of detection of increments of light added to the field must be affected to at least the extent indicated by this fraction.

The quantum efficiency (F), defined as follows, is an absolute measure of the efficiency of performance of a task involving intensity discrimination (Rose, 1948):

$$F = \frac{\text{Smallest possible number of quanta required for task}}{\text{Number required by the eye for performance of same task}}.$$

It can be applied to the detection of near-threshold increments added to a uniform adapting field, in which case the 'task' is regarded as the production of a frequency-of-seeing curve of the same steepness as the one produced by the subject. The numerator is then obtained by a method similar in principle to that used by Hecht, Shlaer & Pirenne (1942) to show that at least 5–8 quanta were absorbed from a flash of light at the absolute threshold; the method is simplified by determining only the two points on the frequency-of-seeing curve corresponding to the intensities seen on about 5 and 95 % of trials. In the present case the stimulus area (0·45 deg^2) and duration (86 msec) were close to those yielding the highest values of F in the rod range in the area of retina used (7° from fovea).

At a background intensity such that 10^7 quanta (507 mμ)/sec. deg^2 enter the eye the compartment hypothesis predicts that only 1/100 of the compartments will remain non-refractory, and measurements show that F is 0·04%, or 1/100 the value with zero background (4 %). However, this agreement only holds at this particular background level: at lower intensities the observed loss is greater than that predicted, whilst at higher intensities it is

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less. Changing the values assumed for compartment size, for photosensitivity of rhodopsin, and for regeneration rate, would not make the predictions fit the experiments over a wider range.

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