gence of the conditioning curves was not a chance one.

Further examination of Table 1 reveals that the CS variable—that is, whether tone or light—also significantly affected the level of conditioning performance. Indeed, this variable gave a slightly larger value of F than did the UCS variable. It will be observed, however, that the interaction term between CS and trial blocks was not significant. This implies that the acquisition curves for the tone and light did not diverge. Presumably the different performance in the case of the two CS's reflects Hull's stimulus dynamism variable, V.

The results of this experiment add still further evidence supporting the interpretation that habit strength (H) is a function of the intensity of the UCS. In the previous experiments (*1*) the performance of two independent groups of S's whose drive level (D) was equated by employing two different puff intensities equally often was compared. It was found in every instance that the group which had the CS paired with the strong UCS exhibited a higher level of conditioning performance than did the group which had the CS paired with the weak UCS. The present experiment involves a comparison of the levels of conditioning to two different CS's, light and tone, established concurrently in the same group of S's. Controlling for any possible effects of the two CS's per se, the analysis of the data of this experiment clearly shows that a higher level of response was given when the CS was paired with the strong UCS than in the case in which the CS was paired with the weak UCS. Since the two conditionings were within the same S, the level of D must have been the same and thus equal for the two CR's. This performance difference reflects, then, a greater development of H in the case of the conditioned reflex established with the stronger UCS.

As the number of conditioning trials in our several experiments concerned with this problem was not sufficient to reach the performance asymptote, one cannot infer for certain whether it is the maximum to which H grows that is related to intensity of the UCS, or whether it is the parameter determining the rate of approach of H to its asymptote. Examination of the curves from the several experiments, including Fig. 1 of the present study, suggests that it is the asymptote of H which is affected and not the rate-of-approach parameter.

In concluding, we should like to call attention once again to the fact that, while the findings of these studies may be interpreted as supporting the drive-reduction versions of reinforcement theory (*5*), we prefer to confine our interpretation to the more general conception that habit formation in such aversive types of conditioning is some function of the intensity of the UCS. Evidence with regard to the precise nature of the reinforcing mechanism in such learning requires other, presumably physiological, types of experimentation.

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Luminosity Curves of Normal and Dichromatic Observers

The question of the relative heights of the luminosity curves of normal and color-blind observers is an important one for theories of color vision, but one which has received very little investigation. If color blindness is due to the absence or inactivation of one or more of the normal retinal receptor-types, a color-blind observer should demonstrate a loss of luminosity in the spectral region to which the missing receptors would normally respond. If the missing receptors were replaced by receptors of a different type, it might be expected that a corresponding enhancement of luminosity would be demonstrable in the spectral region to which this type of receptor was responsive. Alterations in photopigment content of visual cells, substitutions or alterations in the photochemicals themselves, or abnormal retinal distributions of the receptor-types or their neural connections would similarly be expected to produce corresponding luminosity losses and gains. Thus, comparative studies of the luminosity curves of color-defective observers should provide some of the facts necessary, but not yet available, for evaluation of the various theories of color blindness.

Unfortunately, conventionally determined relative luminosity curves provide no basis for direct interobserver comparison of luminosities, since there is no assurance that the standard light to which each test wavelength is matched appeared equally bright to each observer. Abnormalities in the shapes of such curves could be the result of luminosity losses, or gains, or both.

In an attempt to make the desired interobserver comparisons, Hecht and Hsia in 1946 (*1*) determined the relative energy levels of the foveal thresholds of several protanopes, deuteranopes, and normals, for five colors in a 1-deg test field. Plotting relative threshold sensitivities (reciprocals of relative energy) versus wavelength, and measuring the areas under these "luminosity curves," Hecht and Hsia concluded that protanopes lose 49 percent and deuteranopes lose 39 percent of the luminosity of an equal-energy spectrum. Very recently, Hsia and Graham (*2*) repeated these measurements with other subjects. Though their findings differed markedly from those of the earlier study, they nevertheless concluded that there was basic agreement inasmuch as both investigations showed luminosity losses for deuteranopes as well as for protanopes.

One objection to this procedure lies in the fact that the comparisons of observers were made only at the threshold of vision in the dark-adapted eye but were interpreted in terms of photopic luminosities. The stimuli may have been confined to foveal cones [though a 1-deg test spot probably covers about four times the area of the "rod-free" region of the fovea (*3*)], but even this does not permit the inference that photopic brightnesses are in the same relation to each other as are foveal thresholds, either when different wavelengths are compared for a single observer or when different observers are compared at a single wavelength. To afford a basis for photopic comparisons, the use of a photopic visual function would be preferable to the threshold of cone vision as the criterion of equality of brightness. The criterion employed in the present study was equality of the critical frequency of flicker-fusion (CFF) (*4*).

Nine normals, six deuteranopes, and five protanopes served as subjects. The flicker apparatus presented a 5-deg test field (*5*) in Maxwellian view to the subject, who was positioned by means of a mouthbite containing his dental impression. Fourteen narrow spectral regions were isolated as test lights by means of interference filters combined with gelatin filters. Luminance of the test field was varied by neutral filters and a neutral wedge. For these experiments four frequencies of intermittence of the test light were used: 20, 25, 30, and 40 flashes per second, with a light-dark ratio of 1:1. The subject varied the luminance of the test field until flicker was just eliminated—that is, he set the neutral wedge so that the slightest in-

crease in field luminance would result in the appearance of flicker. Each observer made five successive settings at each frequency for the 14 wavelengths tested.

From the calibration data for the instrument, the average wedge settings were translated into relative energies. The reciprocal of the energy requirement for the normal observers at 555 mμ was taken as 100 percent and all other findings were computed as relative luminosities with reference to this one. The results are shown in Fig. 1, together with the CIE luminosity curve for the 1931 standard observer.

A striking feature of these curves is the unusual shape of each, with a sharp notch at 570 mμ and a hump at 590 mμ. The marked lack of similarity to the CIE curve is not unexpected, however, for irregularities of this general nature have been reported by many recent investigators, though the sizes and spectral locations of the variously reported humps and notches have varied considerably.

The results show that at four photopic levels CFF (and, hence, absolute luminosities) of lights of wavelengths shorter than about 520 mμ are substantially equal for protanopes, deuteranopes, and normals. For longer wavelengths protanopes show a loss in brightness, which agrees with the usual explanation of protanopia as a loss system in which the red receptors are absent or nonfunctional. Deuteranopes, on the other hand, show supernormal brightness at these longer wavelengths. The areas under the protanope curves average only 64.7 percent of the areas under the normal curves, indicating a luminosity loss in an equal-energy spectrum of 35.3 percent, while the deuteranopes show an average luminosity gain of 36.2 percent.

The theoretical implications of these findings are numerous and cannot be discussed here. Clearly, however, the finding of deuteranopic brightness *enhancement* (and in the spectral region where protanopes have brightness reduction) constitutes a strong argument against any theory of a "loss" basis for deuteranopia and will necessitate careful reexamination of other existing theories of color vision and color blindness.

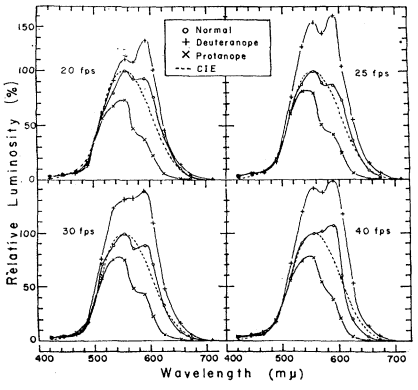

Fig. 1. Luminosity curves of normal and dichromatic observers, showing relative heights at each of four photopic levels. Plotted points represent reciprocals of relative energies required for flicker-fusion at the frequencies indicated. The luminosity curve of the CIE standard observer is included for comparison.

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4. The use of CFF in this way is not to be confused with flicker photometry, an entirely different procedure which utilizes a "standard" light and, hence, is useless for the type of inter-observer comparisons desired here.
5. A 5-deg field was used to minimize individual variations resulting from intramacular structural inhomogeneities (see *3*). Since photopic test luminances were used, it was not necessary to attempt to isolate cone function by means of a small field.

5 May 1958

Biosynthesis of Radioactive Mannitol from $C^{14}O_2$ by Fucus vesiculosus

It has recently been shown that *Fucus vesiculosus* plants produce large amounts of radioactive mannitol during photosynthesis in $C^{14}O_2$ (*1, 2*). Under favorable conditions as much as 95 percent of the radioactivity in alcohol-soluble compounds, or 65 percent of the total radioactivity in the plant, was found in mannitol. This observation suggested a possible method for the laboratory-scale production of radioactive mannitol to be used for subsequent metabolic studies (*3*).

It was found in earlier experiments that the most rapid synthesis of radioactive mannitol in *F. vesiculosus* took place when the plants were suspended in sea water through which air containing 10 percent CO_2 was bubbled (*2*). In the present experiment *F. vesiculosus* plants were collected on a sunny morning in October. A sample consisting of 40 g of sterile fronds cut into 6-inch lengths was immediately prepared and suspended in 700 ml of fresh sea water in the light chamber of a photosynthesis apparatus. A detailed description of this apparatus is given elsewhere (*1*). One gram of $C^{14}O_2$ with a total activity of 5 mc was released in the photosynthesis apparatus to give a gas mixture of 10 percent CO_2 in air. This gas mixture was continuously bubbled through the sea water, and its C^{14} content was automatically monitored and recorded. The plants were held at 16°C and illuminated by water-screened incandescent lamps giving 1600 ft-ca.

After 23 hours of photosynthesis 90 percent of the C^{14} offered had been taken up, and since the rate of photosynthesis had decreased considerably the experiment was stopped. The plants were rinsed quickly in distilled water and extracted thrice with hot 60 percent ethanol. The extracts were evaporated to a small volume in a vacuum and streaked to the short edges of two sheets of Whatman seed-test paper. These were run downwards with sewn-on wicks and stirrups (*4*) in phenol:water (21:8) for 5 days, when the solvent front reached the bottom of the sheets. The strongly radioactive mannitol-containing bands were located by autoradiography and cut out. They were twice eluted with water, and the combined eluates were concentrated to dryness in a vacuum. The crude material so obtained was extracted with 400 ml of boiling *n*-butanol, from which mannitol crystallized on cooling to room temperature. The product was washed with 95 percent ethanol and absolute ethanol followed by ether, and was then dried in a vacuum oven at 50°C.

The yield was 700 mg of mannitol with specific activity of 0.82 mc per millimole. The recovery of supplied C^{14} as mannitol was 63 percent. The isolated mannitol was tested chromatographically in butanol: acetic acid:water, butanol: ethanol:water, phenol:water, and pyridine:ethyl acetate:water solvents and was found to contain no detectable sugar, amino acid, or radioactive impurities. The sensitivity of these tests was sufficient to reveal 0.2 percent of such impurities. Nonradioactive mannitol prepared from *F. vesiculosus* in an identical manner, but using $C^{12}O_2$, was tested for specific rotation and melting point with the results: melting point (Kofler melting point apparatus, corrected), 163° to 164°C; authentic mannitol, 165° to 166°C; mixed melting point with authentic mannitol, 163° to 165°C; $[\alpha]_D^{26}$, +28.4° (c = 1.03, in borax); published value, +28.3°.

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