density of the lake bittern in October 1963) the experimental PVS is 48, and 2.5 percent Mg, 2.8 percent K, and 8.8 percent SO_4 are contained in the deposited salt crystal. Except for the smal' quantities of these constituents, the crystal is sodium chloride. Further evaporation results in an increasing rate of deposition of Mg, K, and SO_4 ions, but crystallization mainly of NaCl, until a density of 1.320 is reached at PVS 12. There much of the sodium chloride has crystallized and a rapid crystallization of salts of Na, K, and SO_4 begins. Density stays constant for a considerable following range. It is supposed this experiment illustrates approximately what occurs during the summer in the northwest body of the lake. It is not known whether, in the earlier stage, Mg, K, and SO_4 are deposited with the NaCl crystals in the form of adhering water, as inclusions in NaCl crystals, or as individual crystals. Industries engaged in commercial recovery of sodium chloride from the lake have found it necessary to limit evaporation in salt recovery ponds to PVS 60 in order to avoid too great a concentration of $MgSO_4$ in the harvest.

3. Use was made of analyses reported by D. C. Hahl and C. B. Mitchell ["Chemcial analyses of water draining into Great Salt Lake, Utah, and of the lake brine," in open-file report of the Quality of Water Branch, Water Resources Division, U.S. Geological Survey, (1963), p. 34] and an additional analysis made in January 1963. On a graph with time as absissa, lake level, total dissolved solids, and proportion of Mg, K, and SO_4 were plotted. The graph shows that the concentration of total salts in the main body of the lake and the proportions of Mg, K, and SO_4 ions have remained essentially constant from 1959 to the present. (This is explained, in the presence of migration of a large quantity of salt from this body, by the coincidental lowering of the lake surface which fortuitously has kept the main body of the lake near saturation during the 5-year period.) Further, it appears from the graph that the proportion of K in the bittern of the northwest body has increased until at the end of the past summer (1963) this proportion was about 60 percent higher than it was in the spring of 1959 when the bittern began as normal lake water. A similar result appears for Mg and SO_4 ions. Among the considerable number of valuable analyses of lake water there are many inconsistencies and much scattering of data. Hence statements made in this report are based as far as possible upon direct observations of the lake and well-established information regarding it. Substantial difficulties interfere with adequate, representative sampling of lake water and the deposited salt layers.
4. Density currents occur when two bodies of water (or other liquid) of different density and usually having a free surface are made to face one another without a separating diaphragm. Density may vary because of temperature, salinity, silt content, and so on. The more dense liquid flows under and toward the less dense, which in turn flows above and counter. Such currents are reported to have been observed in the railroad culverts.

6 January 1964

Light Adaptation Kinetics: The Influence of Spatial Factors

Abstract. *Reducing the target diameter of an adapting (conditioning) flash of light results in a progressive rise in the conventional light adaptation curve, as measured with a small superimposed test flash presented at the end of adapting flashes of variable duration. When both targets are the same size, an abrupt and marked rise in threshold is obtained, resulting from a unique effect that occurs near the termination of the adapting flash. This effect can be demonstrated by means of a variable delay procedure, and it indicates that neural as well as photochemical processes limit the time course of light adaptation.*

It is traditionally assumed that the sensitivity of the visual system invariably decreases (threshold rises) during progressive exposure of the eye to light (*1*). Early psychophysical studies of light adaptation tended to support this viewpoint, since rising functions of negative acceleration were always obtained when threshold luminance was plotted against duration of antecedent light exposure (*2*). In these older experiments, the time course of light adaptation was estimated by measuring threshold with a brief "test" flash of light presented near the end of an adapting (or "conditioning") flash whose duration was systematically increased as the independent variable. More recent psychophysical studies, however, have shown that a different light adaptation function is obtained if threshold for the test flash is measured at various delays (time intervals) from the onset of a concentrically placed and larger conditioning flash of fixed duration and luminance (*3*). Under these conditions, the threshold rises when the test flash precedes the conditioning flash in time, reaches a maximum value near the point of the onset of synchrony (0 delay), and then falls with positive acceleration during the duration of the conditioning flash.

In a previous study in which we used the variable delay procedure just described, we showed that the magnitude of threshold changes over a period of time depended, in part, upon the spatial configuration between the test and conditioning targets (*4*). Specifically, a greater and more lasting change in the monocular threshold was obtained when the diameter of the conditioning target was made smaller and approached that of the brief superimposed test flash. This finding implies that interaction at target border is a critical pararmeter in determining the visual threshold, and supports the argument for a neural rather than a photochemical limiting mechanism (*5*). Before such a sweeping generalization is made, however, it would appear important to determine the role of these same spatial parameters when the time course of light adaptation is estimated in the more conventional fashion, that is, as a function of prior light exposure. This was the object of our study.

By means of a Maxwellian view system (*6*), monocular thresholds were measured in two trained observers (subjects I.H.W. and W.S.B.) by manipulating the luminance of a 5-msec test flash of light (F_t), the onset of which always occurred at the end of a concentrically placed conditioning flash (F_c) of fixed luminance (3.0 log mlam) but of variable duration (from 5 to 1500 msec). Thresholds were similarly measured for the test flash alone (resting threshold, or RT) and for the steady-state condition, in which the conditioning light was continually exposed ("infinite" duration). In all threshold determinations, numerous "blanks" (no test flash) were included to insure reliability and to provide a frame of reference for the observer. The target stimuli were presented upon a constant adapting background of 1 mlam and were centered at 7° of parafoveal displacement along the horizontal meridian in the temporal field of the right eye. The test target always subtended 40′ of visual angle, but the angular subtense of the conditioning target was varied as a parameter from 40′ to 4°40′ in four steps.

The results obtained with both observers are presented in Fig. 1, in terms of test-flash luminance at threshold on the ordinate (in long mlam) and duration of conditioning-flash exposure along the abscissa (in seconds). Four curves are shown for each observer, one for each conditioning-target diameter, as indicated. In confirmation of the earlier reports, these plots show that sensitivity decreased (luminance required at threshold rises) as the duration of prior light exposure was increased. In addition, the data show that the rate of this change in threshold, as well as the asymptotic level finally achieved, became greater with conditioning targets of smaller diameter. This inverse relationship between magnitude of threshold change and size of conditioning target was still apparent when the light emanating from the conditioning target was continuously exposed (∞ duration). It should be noted, however, that under

this latter condition there was an appreciable drop in the threshold increment elicited by the smallest conditioning target (40′ diameter).

The results presented in Fig. 1 indicate that the spatial configuration between test and conditioning targets is a significant factor influencing the time course of light adaptation as measured in conventional fashion. They suggest, moreover, that some unique process is involved when the two targets are of the same diameter. This phenomenon can be better analyzed by comparing the foregoing threshold changes to those which can be obtained with the variable delay procedure (all other conditions being identical). With portions of data from a previously published study (*4*), such a comparison is shown in Fig. 2. Four separate plots are shown for each observer, one for each diameter of conditioning target as indicated. In each plot, the curve marked *M* (line of solid circles) refers to the threshold increments obtained when the test flash either preceded (prior to 0 delay), was superimposed upon (delay, 0 to 0.5 sec), or followed (after a delay of 0.5 sec) a conditioning flash of fixed duration (0.5 sec) and luminance (3.0 log mlam). The curve marked *LA*, in contrast, refers to the data in Fig. 1, where threshold measurements were always made at the termination of a conditioning flash of variable and fixed luminance (3.0 log mlam).

The data in Fig. 2 show that the slope of threshold increments during progressive exposure of light (from 0 to 0.5 sec) depends upon both the method of measurement and the spatial configuration between targets. Negative slopes were obtained with the variable delay method, positive slopes with the variable duration method; the asymptotes in both cases increased with the smaller conditioning-target diameters. With test and conditioning targets of the same size (40′), however, the threshold increments obtained with the variable delay procedure first decreased in magnitude (from 0 to about 0.25 second) and then increased again to a secondary maximum near the end of the conditioning flash (0.5 sec). When the duration of the conditioning flash was increased to 1500 msec (dotted line of circles, marked $F_c = 1500$), this secondary maximum shifted correspondingly in time. It seems clear, therefore, that the marked rise in threshold that was obtained with the 40′ conditioning target of variable duration (curve *LA* of Fig. 2) was due to some unique effect occurring near the end of the conditioning flash.

Although the results of psychophysical studies cannot by themselves reveal underlying mechanisms, they do permit some deductions to be drawn regarding

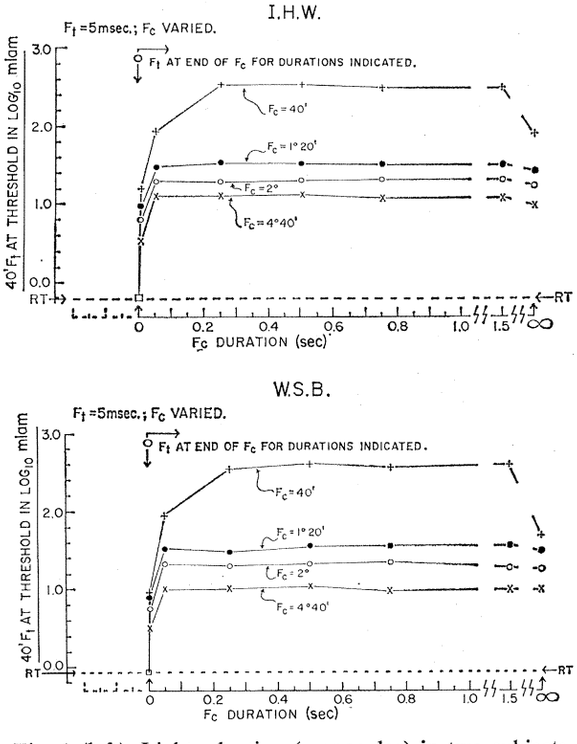
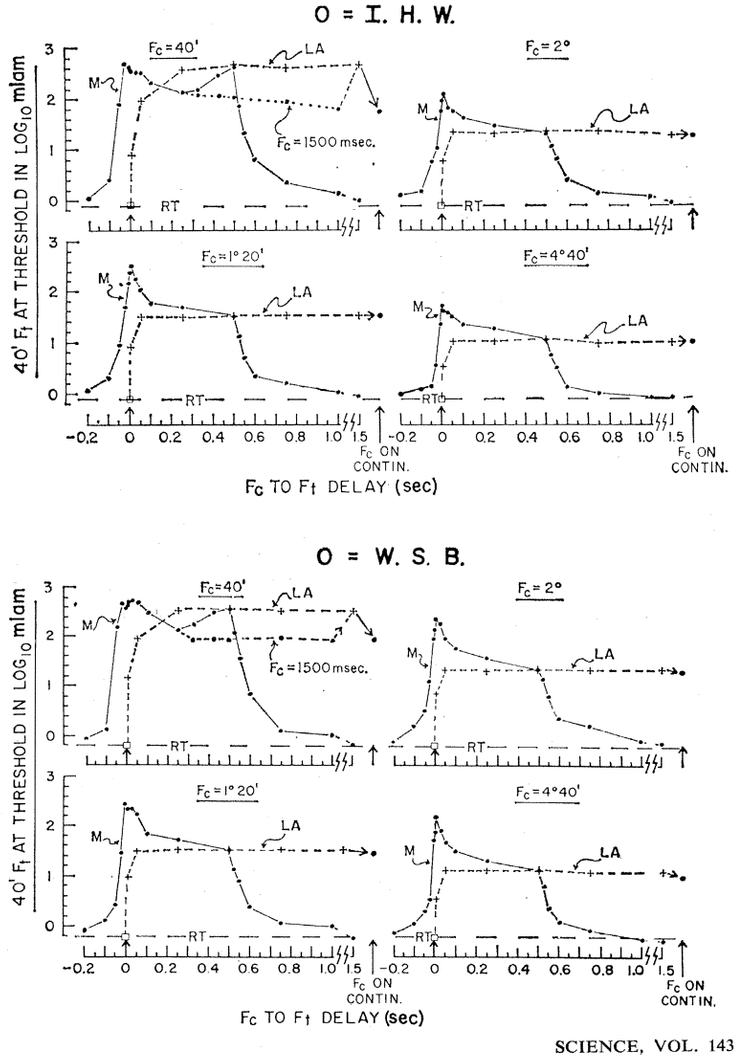


Fig. 1 (left). Light adaption (monocular) in two subjects, I.H.W. and W.S.B. Luminance ($\log_{10}$ mlam) of 40′ test flash at threshold plotted against duration (seconds) of a 3.0 log mlam conditioning flash. Four conditioning-target diameters were used, as indicated (40′, 1°20′, 2°, 4°40′). Thresholds were always measured at the termination of conditioning flash. Fig. 2 (right). Comparison of the adaptation curves in Fig. 1 (marked *LA*) with those obtained by means of the variable delay procedure (marked *M*), for each of four conditioning-target diameters (as labeled). Curves *M* were obtained with a 0.5-sec (or 1.5 sec for $F_c = 40'$) conditioning flash of 3.0 log mlam, by measuring threshold ($\log_{10}$ mlam) at various temporal delays from the onset of the conditioning flash.



promising avenues for further physiological experimentation. From this point of view, the present results indicate that neural as well as photochemical processes are involved in determining the time course of light adaptation, whether measured in conventional fashion or with the newer variable delay procedure. Furthermore, the long-term influence of the spatial parameters shown here suggests that such neural processes are complex and probably involve cerebral mechanisms (*7*). Further studies are necessary to clarify this point.

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6. See optical schematic in W. S. Battersby and I. H. Wagman, *J. Opt. Soc. Am.* **49**, 752 (1959).
7. I. H. Wagman and W. S. Battersby, *Am. J. Physiol.* **197**, 1237 (1959); D. H. Hubel, *J. Opt. Soc. Am.* **53**, 58 (1963).
8. This work was done when we were at the Department of Neurology, Mt. Sinai Hospital, New York, N.Y. It was supported in part by grants B-174, B-294, B-3691, and GM 08013-03 from the U.S. Public Health Service.

6 January 1964

Liquid Film Hygrometer

Abstract. *An improved method of humidity measurement based on the dielectric constant of a liquid-solid mixture has shown agreement with a simple theory. The hygrometer has shown no measurable hysteresis and has identical time-response characteristics for increasing or decreasing humidity.*

Measurement of humidity continues to be a problem in chemistry, geophysics, and other sciences. Most hygrometers are slow to react and lack sensitivity for low humidities; some exhibit hysteresis. The responses of most humidity-measuring devices cannot be related to a suitable theory (*1*). We have succeeded in utilizing the equilibrium between water vapor and a hygroscopic liquid as the basis for a hygrometer which shows promise in alleviating some of these difficulties (*2*).

The equilibrium mole fraction of water in a nonionizing hygroscopic liquid can be related, in the ideal case, to the ambient relative humidity by Raoult's law:

$$\mathcal{R} = \frac{P_w}{P_T} = \frac{n_w}{n_w + n_s} \qquad (1)$$

where $\mathcal{R}$ is the relative humidity at instrument temperature T; P_w is the partial pressure of water vapor, P_T is the partial pressure over water at instrument temperature T; n_w is the number of moles of water, and n_s is the number of moles of solvent.

This liquid may be conveniently utilized as a coating on an inert granular solid, as in gas-liquid partition chromatography. Such heterogeneous mixtures can be formulated with up to 20 percent liquid phase by weight without having a tendency to separate or bleed. Both the bulk resistivity and dielectric constant of a solid-liquid mixture may be expected to vary with the number of moles of water, n_w, but the latter has proved to be more useful.

If the dielectric constant of the mixture is directly proportional to n_w, then for a capacitor containing this heterogeneous material as its dielectric,

$$P_w = \frac{B\Delta C\, P_T}{B\Delta C + n_s} = \frac{\alpha \Delta C P_T}{\alpha \Delta C + 1} \qquad (2)$$

where B is the proportionality constant (moles per picofarad); $\alpha = B/n_s$ and represents the sensitivity constant (pf^{-1}); ΔC is the change in capacitance due to the addition of n_w moles of H_2O (pf).

Figure 1 shows the configuration of a hygrometer with a dielectric composed of a fluorocarbon (Fluoropak 80) coated with polyethylene glycol (Carbowax 400). The capacitor plates are a pair of parallel porous disks of stainless steel, which allow the sample gas to be passed through the capacitor. Because of the high ratio of surface area to mass, and because the liquid is dispersed in a thin layer (about 2500 Å) over the surface, equilibrium can be reached rapidly. The value of α for the hygrometer shown in Fig. 1 was 0.1 pf^{-1}, and the time for half response was 13 seconds at a flow rate of 15 lit./min and a temperature of 20°C. The results in Fig. 2 were obtained under the same experimental conditions; the right side of Eq. 2 is plotted against P_w, indicating the close agreement between equations and experiment. Capacitances were measured with a Tektronix type 130LC capacitance meter.

At low humidities ($\mathcal{R} < 0.1$), the response can be described by

$$\frac{P_w}{P_T} = \alpha \Delta C \qquad (3)$$

since $n_w << n_s$. For low humidity the time response can be described ideally by a simple exponential relationship:

$$\Delta C = \frac{P_w}{\alpha P_T}\left[1 - \exp\left(\frac{-KP_T}{n_s}\, t\right)\right] \qquad (4)$$

where t is the time and K is the diffusion coefficient for water vapor inside the packing.

Since time response and hysteresis are the main stumbling blocks of hygrometers in general, it is appropriate to examine the dynamic characteristics of this instrument. Figure 3 shows a tracing of the response of the liquid-film hygrometer to three step-changes of humidity (two increasing and one decreasing). The humidity changes were from $\mathcal{R} = 0$ to $\mathcal{R} = 0.09$ and back to $\mathcal{R} = 0$, so that the time response equation (Eq. 4) (requiring that $n_w << n_s$) should approximately apply.

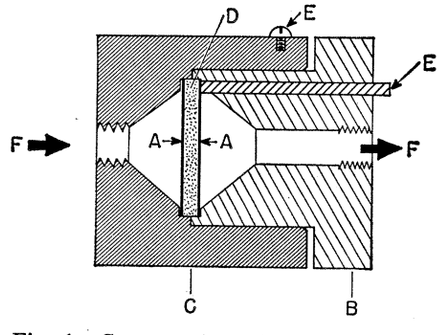

Fig. 1. Cross section of the hygrometer. *A*, Porous stainless steel capacitor plates; diameter, 1.5 cm; spacing, 2.0 mm. *B*, Teflon plug. *C*, Stainless steel body. *D*, Packing material. *E*, Electrical connections. *F*, Airflow.