Since, on the TS-trials, the galvanic skin response to the warning signal frequently merges into the response to the shock itself, it is necessary to devise a means of determining what portion of the total response following shock is actually elicited by the shock. First, the GSR latency was measured, for each shock-alone trial, that is, the time from the onset of shock until the subsequent response had reached 10 percent of its total amplitude (such "10 percent latencies" can be measured considerably more accurately than can the time to the absolute start of the response). These S-trial latencies were then averaged for each five successive trials. The shock-GSR for any TS-trial was then found by laying off one latency period from the start of the shock (by use of the mean for the five S-trials nearest that TS-trial) and measuring the amplitude from that point to the peak of the shock-GSR. This value was taken as being 0.9 of the total galvanic skin response actually elicited by the shock on that TS-trial. Since most of these animals showed a moderate negative ptype correlation between GSR amplitude and latency, this scoring procedure tends to err in the direction of reducing the expected differences. The preception hypothesis predicts that the galvanic skin responses on the TS-trials shall be smaller than those on the S-trials, hence their latencies should be somewhat longer also; the scoring procedure used here would therefore tend to overestimate GSR amplitudes for the TS-trials.



Fig. 2. Solid curve shows ratio of GSR amplitude on tone-shock (TS) trials to amplitude on shock-alone (S) trials as a function of the duration of the tone or warning interval. Broken curve shows similar ratio of the variances (across trials) or GSR amplitudes.

Mean GSR amplitudes were computed for successive blocks of five Strials and five TS-trials. For each such block of five pairs of trials, a preception score was obtained by dividing the mean TS-GSR by the mean S-GSR; this ratio represents the shock response on the TS-trials as a fraction of the response shown on the interpolated Strials. These values are plotted for each warning interval group in Fig. 1. The TS-GSR was always smaller than the S-GSR except for one point on the 10second curve and another on the 5-second curve. Thus, the expected negative preception effect is apparent. Moreover, the effect appears to be strongest for the 1-second warning interval and least for the two longest intervals. The overall mean preception ratios for the five interval groups are plotted in Fig. 2. For the 1-second group, the TS-GSR averaged only 47 percent of the S-GSR amplitude but was about 65 percent for the 0.5 and 2-second intervals and over 85 percent for the 5- and 10-second intervals.

The preception hypothesis also predicts that the responses to the more predictable shocks should be less variable from trial to trial than those produced by the shocks given alone. Therefore, the warning interval which is optimum for preception should yield the smallest ratio of TS-GSR variance to S-GSR variance (these variances being computed over the eight blocks of five trials each). This variance ratio is also plotted in Fig. 2 and shows the expected result. For the optimum 1-second interval, the variance of the TStrials is only about 4 percent of the variance on the S-trials; for the 0.5 and 2-second intervals, the values are 32 and 53 percent, rising to 94 and 74 percent for the 5- and 10-second groups, respectively.

An immediate practical implication of these findings concerns the widespread use of shock or other brief noxious stimuli in behavioral studies of stress, emotional learning, and the like. The data make clear that the effective intensity of a stimulus having a constant physical intensity may vary greatly from trial to trial unless the time of occurrence of the stimulus is made predictable for the subject. Whether the optimum warning interval is the same for the human and other species as for the rat remains to be determined (7).

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Retinal Receptor Potentials and Their Linear Relationship to **Light** Intensity

Abstract. After treatment of the isolated retina of a fish (Centropomus) with ammonia (NH₃), the electrical responses to light are confined to the receptor layer. These receptor responses are fast in light adaptation and very slow in dark adaptation. The light-adapted responses have thresholds 3 to 4 logarithmic units of light intensity higher than the darkadapted ones. Both kinds of responses are linearly related to light intensity up to the appearance of saturation. Interactions between receptors and adjacent glia cells appear to be involved in adaptation.

This report presents some of our recent electrophysiological observations on the isolated retina of the fish (Centropomus). The data elucidate the form of the relationship between the response of photoreceptors and the light intensity. Evidence on this relationship in the experimental literature is inconclusive. The slow, graded potentials recorded from Limulus ommatidia (1) are intracellular and are linearly related to the logarithm of the light intensity. There is, however, no firm evidence at the present time that these and similar graded potentials are the primary responses of the photosensitive structures (2). The electroretinograms of different animals also follow a semilogarithmic law (3), the cornea-negative *a*-wave being considered to indicate the early onset of the PIII component. Although Granit (3) considers that this component probably originates from the receptors, he relates it to inhibition. The local positive (receptor surface) responses obtained by small light spot stimulation of the isolated fish retina (4) vary semilogarithmically with light intensity. These responses result from positive re-

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sponses originating in the receptor layer and negative responses originating well below the surface (5). Despite this persistent semilogarithmic relationship, Rosenberg's (6) photoconductivity studies of β -carotenoid are of interest, since this pigment may be concerned in the primary process of vision. Rosenberg found that "the steady photocurrent is directly proportional to the light intensity at moderately high intensity." Further, from psychophysics it is known that in the fovea Ricco's law holds for fields involving up to about 20 cones, and Willmer (7) deduces from this that the receptor responses are linearly related to light intensity. Some time ago (8) we concluded that such a linear relationship was true for the primary receptor process. This evidence was indirect, being based on an examination of the glial (horizontal) cell response in the fish retina illuminated by two light spots. We now have rather direct evidence that the linear relationship holds.

Our investigation has shown (9, 10)that application of a small amount of NH^s to the isolated retina of fish abolishes all glial and neuronal activity. Mitarai et al. (11) found that after NH₃ treatment of a retina isolated from a light-adapted fish, a microelectrode on the receptor surface records a graded positive (same polarity as PIII) fast response of rectangular shape and short latency (5 to 10 m/sec). This response is undoubtedly associated with the photoreceptors, since it can be recorded only across the receptor layer. A summary of our recent results for the isolated retina (without pigment epithelium) of fish is given below. Diffuse white light illumination was used; the responses were recorded by a glass microelectrode (2.5M KCl, about 20 megohm) in contact with the receptor surface, the indifferent electrode being on the vitreous side of the retina.

If the retina is isolated from a darkadapted (24 hour) fish and NH3 is applied; then, as compared to light adaptation, the receptor response threshold is lower by 3 to 4 log units of light intensity and the responses are much slower (rise times more than 1 sec and decay times up to 20 sec). Figure 1 shows the relationship between receptor response and light intensity. Curve a is for an NH₈-treated retina isolated from a dark-adapted fish, and curve b is for the other retina of the same fish, but light-adapted before NH₃ application. During the experiment on the darkadapted retina, some light adaptation 31 AUGUST 1962

2000 (a) ESPONSE (µV DARK-ADAPTED 1000 100 (b) LIGHT-ADAPTED 10 5 6 7 3 4 8 LOG 10 (REL.LIGHT INTENSITY)

Fig. 1. Relationship between surface (receptor) response and light intensity for *Centropomus* retina. Dashed line shows slope required for linearity.

was practically unavoidable. The neutral-density filters used for light intensity control could be changed rapidly, but only within a certain range. During the time necessary to pass from the low light intensity ($\overline{9}$.6 to $\overline{8}$.8) range to the higher one, the retinal sensitivity decreased as shown by the break in curve a at $\overline{7}$ on the log light intensity scale. In the experiments on which Fig. 1 is based the illumination was diffuse, but we have also used small spot (80 μ in diameter) illumination of the lightadapted retina and obtained a similar result to that shown in curve b. In this case the surface positive responses prior to NH₃ treatment were nonlinearly related to the light intensity, increasing at a much slower rate than the stimulus from near threshold.

Curves a and b both have a linear range of about 1.6 log units of light intensity. In other experiments for the light-adapted responses, we have obtained a linear range of up to 4 log units. Since the light-adapted (fast) responses show a Purkinje shift when compared with the dark-adapted (slow) ones (11), it may be presumed that curves a and b respectively relate to the rods and cones.

The mechanism of the adaptational change of the receptor responses shown by the shift from curve a to b is of interest. We found that it was impossible to produce the fast light-adapted responses from the isolated retina treated with NH₃ while it was still dark-adapted. The initial effect of light adaptation was to raise the threshold for the slow responses, the threshold still remaining

well below that of the fast responses. With further light adaptation it became impossible to elicit responses with even the maximum light intensity available. On the other hand, the fast responses could be obtained if the isolated darkadapted retina was light-adapted before NH_3 application. It is known (11) that the glial cells (horizontal cells and Müller fibers) have graded responses and steady potentials which closely follow adaptational changes. The responses are slow in dark and fast in light adaptation, show a Purkinje shift, and the resting potentials of the glial cells increase with light adaptation. The glial cells and neurons of the fish retina are extremely sensitive to NH₃ (10), and sufficient dosage entirely suppresses their activity. Since in our experiments the pigment epithelium was removed, the radial Müller fibers were the only glia in the outer retina. These structures are in intimate relationship with the inner segments of the receptors (12). Further, Noell (13) adduces evidence that there is an active component of ion exchange between the outer parts of the receptors and the "glial" pigment epithelium, contributing to the C-wave. It is therefore a reasonable supposition that there is normally an interaction between the Müller fibers and the receptors. This interaction, which can be disrupted by NH₃, is an important factor in retinal adaptational changes.

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Concentration of Cesium-137 in Human Rib Bone

Abstract. The concentration of fission product cesium-137 in human rib, sampled from various age groups, has been determined by low-level gamma-ray spectrometry. We propose several possible interpretations of the data and point out the possibility that mechanisms of cesium retention may be age-dependent.

The presence of fission-produced cesium-137 in human beings has been extensively studied since it was first reported in 1956 by C. E. Miller and L. D. Marinelli (1). C. E. Miller (2) reports a value of approximately 30 $\mu\mu c$ of Cs¹³⁷ per gram of potassium for adult residents of the Chicago area during the summer of 1961. This figure indicates a level of $\sim 6 \times 10^{-14}$ curie of Cs¹³⁷ per gram of wet tissue weight (135 g of potassium in a 70-kg man) or 1.35 \times 10⁻¹³ curie per gram of wet muscle assuming that all the Cs137 is concentrated in 30 kg of muscle. It has been found from animal experiments (3, 4)that the greater part of the Cs¹³⁷ is in the muscle; however, the work of Nelson. et al. (4) with laboratory mice indicated the concentration of intravenously injected Cs¹³⁷ to be highest in cartilage. Because of the low concentration of potassium in bone mineral, bone has never been considered a likely site of cesium deposition or accumulation. However, in chemical analyses of bone specimens from cadavers, Yamagata

et al. (5) reported the presence of Cs¹³⁷ and proposed that the cesium was located in the marrow rather than in the bone itself.

The experiment considered in this report (6) was designed to determine whether Cs137 was actually present in bone, and if so, whether a relationship existed between the concentration and the age of the subject. Rib was chosen because the cesium concentration is highest in this bone (5) and because rib sections may be easily obtained at autopsy. Seventy rib specimens were obtained through pathologists in the Chicago area, ten specimens from each of the following age groups: 0 to 5, 6 to 10, 11 to 20, 21 to 30, 31 to 40, 41 to 60, and over 60 years of age. Collections were made between April and the end of August, 1961. Hence no radioactivity from the Soviet 1961 tests was involved in this investigation. A short history was obtained with each specimen, and only specimens from victims of accidents or short-term diseases were selected, to avoid possible changes in mineral metabolism which might have occurred from long illness or prolonged therapy. Specimens were individually ashed at 400°C after adhering tissue had been removed, and the ribs were split and mechanically brushed free of marrow. Each sample was scanned for abnormal amounts of radioactivity by means of a scintillation counter. The samples for each age group were pooled, and the composite sample was then counted by means of a sodium iodide crystal (5 in. in diameter and 4 in. thick), in a low-background shield, and a multichannel analyzer. The only gamma emitters detected were cesium-137 and potassium-40, although an effort was made to detect cerium-144 and ruthenium-106. Concentrations of Cs137 and K40 were obtained by counting standard sources of these radionuclides under identical conditions. The mean value for three measurements of each sample in terms of curies of Cs187 per gram of bone ash is plotted in Fig. 1, and the standard deviation is also indicated. Because of the relatively long counting times used for sample and background determinations (900 to 1000 minutes) the probable errors are small.

From the data presented in Fig. 1 we have drawn several tentative conclusions.

1) Cesium-137 is apparently present in rib bone and, in fact, appears to be present in concentrations equal to or somewhat greater than either the whole-



Fig. 1. Cesium-137 in pooled rib samples. (Circles) Values of Anderson and Gustafson (70 specimens); (crosses) values of Yamagata et al. (12 specimens).

body average or the mean concentration in muscle.

2) This finding implies that Cs¹³⁷ may be a more important internal emitter, due to its retention in bone, than had previously been thought. Confirmation or refutation of this possibility is essential in view of the resumption of nuclear testing. Suffice it to say that the radiation dose to adult rib bone in 1961 in the Chicago area was greater from Cs187 than from strontium-90, to judge by the average Sr⁹⁰ values in adults found by Kulp et al. in 1959 (7).

3) The decrease in the concentration of Cs¹³⁷ with age up to 15 years seems to follow the pattern of ossification of cartilage, and concentration in this soft tissue may be responsible for the relatively high levels in the 0- to 5-year group, as suggested by the findings of Nelson et al. (4). Either the cesium is then eliminated as ossification proceeds, or the initial uptake is lower in the older children.

4) The postpubertal rise in cesium concentration also evident in the data of Yamagata et al. (5) (Fig. 1) cannot at present be explained and requires further investigation.

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