

newborn or newly hatched reptiles appear to tolerate anoxia no better than adults. Current data suggest the possibility of significant seasonal differences in some species, but as yet there is insufficient information to confirm this.

The great intraspecific variation in tolerance of anoxia (coefficient of variation often greater than 20 percent) suggests that this trait is in itself of small adaptive significance, since characters maintained under strong selection pressure should show little random intraspecific variability. To determine the correlates of this variation, it is necessary to test statistically large numbers of individuals of each of a few selected species. A number of phylogenetically important groups, such as the Sphenodontidae, Dermochelyidae, Amphisbaenidae, and Typhlopidae also remain to be tested.

Knowledge of the distribution of tolerance of anoxia among reptiles is making possible a more effective study of the biochemical mechanisms responsible for the anaerobic survival of amniotes. I have previously suggested that the low metabolic rate of turtles (in contrast to mammals, who have much greater energy requirements) might allow them to survive anaerobically by utilizing the small energy yield of glycolysis alone (5). Since the energy requirements of other reptiles are about the same as those of turtles, the much shorter tolerance times for lizards, snakes, and crocodilians make it clear that the situation is more complex. Perhaps the explanation is related to the fact that turtles have much higher con-

centrations of bicarbonate ion in their body fluids than do other reptiles (6) and are thus better able to buffer anaerobically produced acid metabolites. The approximate ratio of plasma bicarbonate for turtles : sea turtles : other reptiles is 5 : 3 : 2. This ratio fits qualitatively with relative tolerance times but is quantitatively sufficient to explain less than half the difference. Measurements of total body buffer capacity and of lactic acid and carbon dioxide production during anoxia may clarify this problem and may indicate whether these reptiles have more exotic metabolic mechanisms. Carp exposed to long-term anoxia form fats, rather than lactic acid (7), and the possibility remains that turtles are also able to utilize anaerobic hydrogen acceptors other than pyruvate and produce substances less disturbing to tissue pH than lactic acid (8).

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Scotopic Spectral Sensitivity in the Monkey

Abstract. *Three rhesus monkeys learned to adjust a small illuminated spot to threshold intensity. Then, while dark adapted, they "tracked" their thresholds to stimuli spaced across the visible wavelength spectrum. Spectral sensitivity functions were determined for each animal from these threshold records. The functions agreed well with results obtained from a human subject in the same apparatus, and with the standard human scotopic function defined by the International Commission on Illumination. However, the monkeys' relative sensitivity was slightly higher in the long-wavelength portion of the spectrum.*

A great deal of behavioral and physiological work is being done with monkeys, yet there is a lack of detailed information on the sensory capacities of these animals. Recently, new behavioral techniques for obtaining such psychophysical data have become available. The research reported here (1) uses one such technique to determine the dark-adapted absolute threshold of

rhesus monkeys as a function of stimulus wavelength.

The method was devised by one of us to determine absolute thresholds in the pigeon (2). The procedure is often called "tracking" and is based on a method of human audiometry invented by Békésy (3). The subject keeps the stimulus intensity varying up and down across its absolute threshold by alter-

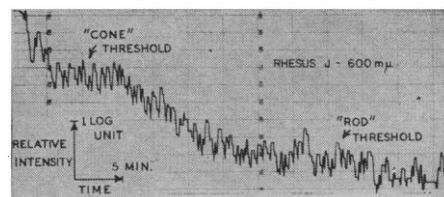


Fig. 1. Dark adaptation curve of a monkey after previous exposure to a white screen illuminated by photoflood lights. Note the two segments, first "cone," then "rod."

nately pressing on two levers, and a continuous record of the intensity "tracks" the threshold through time.

The subjects were three young rhesus monkeys, two male and one female. During an experimental session, the monkey sat in a restraining chair in a small light-tight room facing a stimulus panel. The collar of the monkey's chair held its head with the eyes about 25 cm from the panel. On the panel was a circular stimulus patch 18 mm in diameter. Two response levers protruded below the patch. The monkey's task was to press the left lever repeatedly when the patch was visible, and the right lever when the patch appeared dark. This behavior was maintained by a chain of events that led to food reinforcement. Two or three times a minute, presses on the left lever closed a shutter in the stimulus beam path. When the stimulus had been turned off in this way, presses on the right lever caused a banana flavored pellet (4) to fall into a cup between the levers. However, the shutter and the pellet dispenser were activated by the levers only at randomly spaced intervals. At other times, presses caused the rotation of an optical wedge located in the stimulus beam. Presses on the left lever moved the wedge in such a way as to reduce the stimulus intensity, and presses on the right lever acted to increase the intensity. As a result, the stimulus kept oscillating about the monkey's threshold. When the stimulus disappeared below threshold, the monkey pressed the right lever, causing the stimulus to get brighter; when the patch became visible, the monkey pressed the left lever, causing the stimulus to dim and disappear. The monkey had no way of knowing when this tracking procedure, rather than the shutter-food pellet sequence, was in effect, so it gave a steady stream of responses. This procedure has complexities not mentioned here; further details are described elsewhere (5).

After a few weeks of practice the monkeys became proficient at the tracking task. Changes in the stimulus lumi-

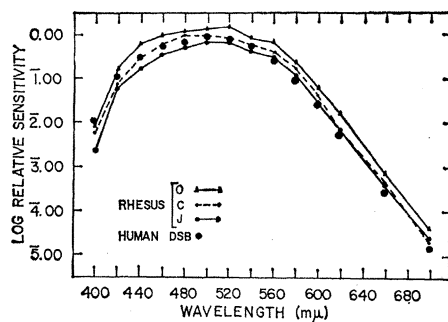


Fig. 2. Mean sensitivity curves of three monkeys and one human subject. Each point of the monkey data includes 15 to 18 separate determinations. The human data agree closely with the standard scotopic spectral sensitivity function defined by the International Commission on Illumination.

nance or the monkey's threshold brought a prompt compensating adjustment. Figure 1 shows a sample of the precise way in which monkeys followed threshold changes. It records the intensity adjustments made by one monkey as its threshold fell during dark adaptation.

For the spectral work, a Bausch & Lomb grating monochromator delivered light of selected wavelengths (bandwidth 6.6 mμ) to the stimulus patch. During experimental sessions the only light in the monkey's room came from this patch. The light passed through neutral filters, color filters designed to reduce stray light, and finally through the motor-driven optical wedge. The position of the wedge was recorded on a strip chart (see Fig. 1) and thresholds were determined from these records by taking account of energy and transmission values at the several stimulus wavelengths.

Before each experimental session the monkey spent at least 1 hour in complete darkness, out of reach of the response keys. Then, in dim light, it was wheeled into position and the apparatus was turned on. Eight or more wavelengths were presented each day, in a

randomized sequence, for 15 minutes each. Data from the first 10 minutes of each session were discarded. Between 15 and 18 threshold determinations at each wavelength were averaged to produce each monkey's sensitivity function.

The results appear in Fig. 2. Curves for each of three monkeys are shown, and, for comparison, the values obtained from one human subject in the same apparatus appear also. The human data may perhaps be considered representative, for they deviate little from the standard scotopic spectral sensitivity function for young eyes defined by the International Commission on Illumination. The relative deviation amounts to less than 0.1 log unit at all wavelengths.

It may be seen that the monkey functions agree well with one another. They are also quite similar to the human sensitivity curve, although in the long wavelength region (560 mμ and greater) the monkey's relative sensitivity appears to be slightly but consistently greater than the human's. General agreement with the human function is not unexpected, since both are presumably based on the absorption spectrum of rhodopsin, the photosensitive pigment in the "rod" elements of both monkey and human eyes. The significance of the slightly deviant long wavelength sensitivity is not clear.

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Polymer Structure: Cross-Linking of a Polybenzimidazole

Abstract. *The torsional braid technique was used to monitor the changes in rigidity and damping characteristics of a polybenzimidazole as it changes from a thermoplastic polymer to a thermoset resin at about 450°C. In an intermediate process the thermoplastic backbone of the polymer becomes flexible.*

By thermal treatment at about 500°C, a polybenzimidazole becomes insoluble; this has been attributed to cross-linking (1). This report presents the

results of an investigation of the thermomechanical properties of a composite of glass braid and polybenzimidazole, in which changes in dynamic mechan-

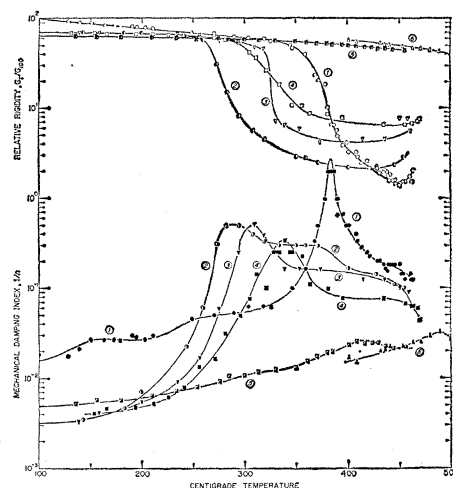


Fig. 1. Cross-linking of polybenzimidazole.

ical properties of the composite were monitored by torsional braid analysis (2, 3). The changes in mechanical properties of the composite are interpreted in terms of changes in the polymer. Two concurrently determined parameters are used in the technique as a qualitative measure of the mechanical properties. The relative rigidity, G_T/G_{100} , expresses the rigidity modulus at some temperature T , relative to the arbitrary reference state of the initial composite of polymer and substrate at 100°C. The damping-index parameter, $1/n$, which is introduced in this short report represents an attempt to obtain a measure of the mechanical damping by counting the number of oscillations, n , which the eye can distinguish upon the induction of a free vibration. The two parameters have a physical basis, and the approach supplies reproducible data. The apparatus and experimental methods have been described previously (3). The polybenzimidazole (4), poly-2,2'-(*o*-biphenylene)-5,5'-bibenzimidazole, is soluble in formic acid and has an intrinsic viscosity of 2.95. Polymer (0.1 gram) was deposited on the glass braid from a 10 percent solution in formic acid.

The thermal softening behavior of the initial polymer-glass composite (cycle No. 1 of Fig. 1, in 4 hours) demonstrates the thermoplastic nature of the polymer. A glass region, a glass transition region (about 390°C), and a rubbery region are each well defined. Since the polymer as synthesized was linear, albeit conjugated, the characteristics are not unexpected. Above about 450°C, the increase in rigidity and decrease in damping are attributed to cross-linking. After cooling, the heating