References and Notes

1. B. K. Anand and J. R. Brobeck, *Yale J. Biol. and Med.* **24**, 123 (1951).
2. M. Brugger, *Helv. Physiol. et Pharmacol. Acta* **1**, 183 (1943); S. Larsson, *Acta Physiol. Scand. Suppl.* **32**, 115 (1954); N. E. Miller, *Science* **126**, 1271 (1957); P. J. Morgane, *ibid.* **133**, 887 (1961).
3. O. A. Smith, *Anat. Record* **124**, 363 (1956).
4. A. N. Epstein, *Am. J. Physiol.* **199**, 969 (1960).
5. S. P. Grossman, *Science* **132**, 301 (1960).
6. W. Wyrwicka and C. Dobrzecka, *ibid.* **132**, 805 (1960).
7. J. R. Brobeck, J. Tepperman, C. N. H. Long, *Yale J. Biol. and Med.* **15**, 831 (1943).
8. J. Olds, *Am. J. Physiol.* **199**, 965 (1960).
9. Details of electrode-cannula construction will be sent upon request.
10. P. Teitelbaum and B. A. Campbell, *J. Comp. and Physiol. Psychol.* **51**, 135 (1958).
11. D. L. Margules, paper delivered at meeting of Eastern Psychol. Assoc. (1961).
12. J. Olds, *J. Comp. and Physiol. Psychol.* **51**, 320 (1958).
13. A 10-minute movie is available. It shows the major effects that have been reported here. Special thanks are extended to Drs. Alan N. Epstein and Eliot Stellar for their valuable suggestions. This research was supported by the National Science Foundation (grant No. G-9792).

13 October 1961

Self-Regulated Exposure to Light by Dark- or Light-Treated Rats

Abstract. Rats allowed to expose themselves to light do so for a rather constant length of time each day. This duration of exposure depends upon both the brightness of the light used for testing and the illumination in which the rats were maintained before testing.

The albino rat had long been characterized as aversive to light (*1*) when Marx (*2*) showed in 1955 that onset of light was positively reinforcing. This unexpected effect has been repeatedly confirmed, and the current interpretation is that onset of light is reinforcing because of the change in stimulation (*3*). An alternative hypothesis is that there exists a preference function across luminance which reaches a maximum in the "dim" region and then decreases as luminance is increased. In this report I attempted a direct test of the preference hypothesis by allowing rats to choose between darkness and one of a number of illuminations of the cages in which they were maintained.

A second variable investigated was the effect of luminance of maintenance quarters prior to testing. With few exceptions, experimenters have tested the reinforcing or aversive effects of light without regard to pretest conditions of luminance. Since past results show that a given luminance can be reinforcing in one study and aversive in another, it seemed possible that this inconsistency could be due to differences in lighting between different animal maintenance quarters.

Male albino rats were kept in either darkness or bright light (100 mlam) in identical cages for 12 days, then put, one to a chamber, into test chambers with two levers. When the animal pressed one lever, the chamber's diffused overhead light came on and stayed on until the other lever was pressed. Each animal could thus control how long its light was on. Different chambers had lights of 0.01, 0.1, 1.0, 10, or 100 mlam (*4*). Each animal was left in a given chamber for 12 consecutive days without disturbance. Food and water were always available by feed-through tubes. Athough 40 rats were pretreated and tested, seven were discarded for nonresponding and three more to allow a balanced statistical analysis.

The number of minutes that each chamber's light was left on each day was recorded. Figure 1 shows the mean daily duration that each light was kept on by the dark- or light-treated animals tested with it. Each of the ten functions shown is the mean performance of three animals across 12 days.

When tested in chambers that had a very dim light, rats kept in darkness for 12 days before testing showed no significant difference from light-treated animals in the daily durations of self-exposure to light. When given control of a 1-mlam light, however, dark-treated rats soon shifted to durations significantly shorter than those of the light-treated group ($p < .001$) (*5*). In 10 and 100 mlam, both groups eventually chose very short daily durations of light, but the dark-treated animals did so sooner in both cases ($p < .05$). Furthermore, the differently pretreated groups showed a small but consistent difference between the asymptotes of their light-duration functions for the last 6 days in 10 mlam ($p < .01$) and the last 3 days in 100 mlam ($p < .05$).

The long daily durations of light chosen by rats in 0.01 and 0.1 mlam show that dim light is somewhat preferred over darkness. Short durations in higher luminances show the reverse, that is, darkness preferred over light. Thus the reinforcing properties of the onset of dim light are at least partly due to the preference value of the absolute luminance produced by the response, and not entirely to the change in stimulation. Similarly, the reinforcing properties of the offset of bright light (*1*) reflect the preference for darkness shown by rats of the present study tested in 10 and 100 mlam. The finding of Barnes (*6*), that a change of dim lights from "on" to "off" is not reinforcing, further strengthens the preference hypothesis. Furthermore, this hypothesis unites the results of the earlier light-aversion studies with the later light-reinforcement studies, suggesting a single and quantifiable theory of luminance-controlled behavior.

The finding that dark-treated rats strongly prefer darkness to 1.0 mlam while light-treated ones keep the 1-mlam light on for substantial periods introduces a complication in the determination of a preference function across

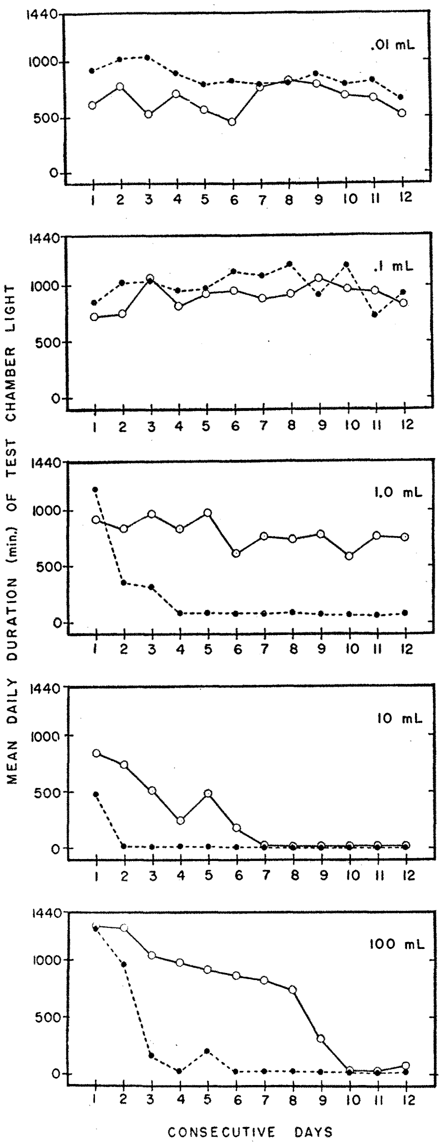

Fig. 1. Mean daily duration of albino rat's self-exposure to various luminances (indicated at upper right of each plot) as a function of time. Dark circles indicate rats kept in darkness for 12 days prior to testing; open circles, rats similarly kept in 100 mlam. (1440 min = 24 hr).

luminance. It would seem that there is not a single function, but more probably a family of functions with maintenance luminance as the parameter. Thus studies of light-controlled behavior which use rats from environments of unspecified luminance will not bear comparison with one another; and animals housed in a laboratory between test sessions are not just "stored," but are receiving a treatment (*7*).

ROBERT B. LOCKARD
Department of Psychology,
University of Wisconsin, Madison

References and Notes

1. F. S. Keller, *Psychol. Record* (May 1941); L. F. Hanson, unpublished Ph.D. dissertation, Columbia University (1951).
2. M. H. Marx, R. L. Henderson, C. L. Roberts, *J. Comp. and Physiol. Psychol.* **48**, 73 (1955).
3. J. W. Kling, L. Horowitz, J. E. Delhagen, *Psychol. Repts.* **2**, 337 (1956); H. Levin and D. G. Forgays, *J. Comp. and Physiol. Psychol.* **52**, 195 (1959).
4. All luminance measures are from a Macbeth test plate on the floor of the cage.
5. The probability values after statements were derived by analysis of variance, except the last two, which resulted from *t*-tests.
6. G. W. Barnes, G. B. Kish, W. O. Wood, *Psychol. Record* **9**, 53 (1959).
7. I was a National Science Foundation predoctoral fellow during the period in which this work was done.

18 September 1961

Vertical Extension of Mid-Continent Leonardian Insect Occurrences

Abstract. Two new Permian insect-bearing beds are reported. To date, these are geologically the oldest and youngest found in the Wellington formation of Kansas and Oklahoma. Altogether, six such beds are now known. When these beds are stratigraphically placed in relative elevation above the marine Herington limestone, they are found to recur at intervals of approximately 100 feet.

Prior to the present field study, two insect-bearing beds were known from the Wellington formation: the Midco (*1*) and Carlton (*2*). The first indication that other insect-bearing beds were present in this formation came from the discovery of a traceable conchostracan-insect horizon in Marion, Harvey, and Sedgwick counties, Kansas (*3, 4*). Subsequently, a fourth traceable insect-bearing bed was found in Oklahoma and Kansas (*5*). Some of the fauna of the fourth bed has since been described, and the bed has been designated as the *Asthenohymen-Delopterum* bed (*6*).

While searching for the contact of the Milan member (uppermost unit of the Wellington formation) and the next underlying beds, I discovered a fifth insect-bearing bed in Kay County, Oklahoma (locality: Wellington XIX, SE, NW, sec. 20, T29N, R2W). This insect-bearing bed is 30.4 feet above the base of the section, which is at the level of the Chikaskia River. Geologically, it is the youngest Wellington insect-bearing bed found to date.

An exploration to locate contacts between units in the lower 200 feet of the Wellington formation led to the discovery of a sixth, and geologically the oldest presently known, Wellington insect-bearing bed. It was found in Sumner County, Kansas (locality: Wellington XVIII, NW, NE, sec. 23, T34S, R2E). The base of the section at this locality is in a creek floor and the insect-bearing bed is exposed in a road ditch about 19.0 feet above the base.

As previous workers have pointed out (*1, 2*), one must rely on subsurface data to place the insect-bearing beds accurately. The top of the Annelly gypsum is a useful surface datum, although it is spottily exposed or absent from critical localities. The top of the marine Herington limestone is the most satisfactory datum but absence of exposures at critical localities compels one to rely upon subsurface data. Based on subsurface data, Raasch (*1*) placed the Midco beds at 550 feet above the top of the Herington, and Dunbar (*2*) placed the Carlton insect-bearing beds at 250 to 300 feet above the Herington.

The present study establishes that the conchostracan-insect horizon in Marion, Harvey, and Sedgwick counties, Kansas, is about 10.0 feet above the top of the Annelly gypsum. Because the top of the Annelly, as determined in the field, is about 40.0 feet below the Carlton insect-bearing bed, the top of the Annelly must be between 210 and 260 feet above the top of the Herington.

Stratigraphic placement of the two new insect-bearing beds requires a brief explanation. The oldest insect-bearing bed (Wellington XVIII, Sumner County, Kansas—see Table 1, OIB) crops out a little more than 9 miles east of the Kansas Turnpike. Another section in Cowley County, Kansas, 4½ miles east of Wellington XVIII and stratigraphically below it, exposes the basal 50 feet of the Wellington in which no insects were found. At this place, the Wellington rests directly on exposed Herington limestone. Finally, along the Turnpike, a section was found in which the basal gypsiferous shale overlies the top of the Annelly gypsum. Thus, between the Turnpike section and the top of the Herington in the Cowley County section, there is an interval of about 210 feet (derivation of this figure was given in the preceding paragraph). It follows that the Wellington XVIII insect-bearing bed must occur in an interval between 50 and 210 feet above the top of the Herington.

Field relationships (negligible regional dip to west, distances between outcrops) indicate that the insect-bearing bed is closer to the top of the Herington than to the top of the Annelly by a factor of two. This, in turn, permits the estimate that stratigraphically it occurs 50 to 70 feet above the top of the Herington.

The new insect-bearing bed in Kay County, Oklahoma (Wellington XIX, see Table 1, YIB) can be stratigraphically placed by the following line of reasoning: Raasch's Midco bed is 550 feet above the Herington. Some 53 feet of section were measured above this bed in Noble County, Oklahoma. No insects occurred in the upper 45 feet of this section. That can account for 603 feet of the Wellington (that is, 550 feet plus 53 feet). The total thickness of the Wellington is some 700± feet. Thus, the top of the uppermost member of the Wellington, the Milan, must lie 97 feet above the top of the sections measured in Noble County (that is, 700 feet minus 603 feet). However, some 32 feet of section were measured below the top of the Milan limestone (Wellington XI, Sumner County, Kansas) and no insects were found. Accordingly, the Wellington XIX insect-bearing bed appears to occur in the interval 603 to 668 feet above the Herington (that is, 700 feet minus 32 feet).

Another possibility needs consideration. A green copper carbonate stain was noted in a hard, argillaceous limestone some 10 feet above the Wellington XIX insect-bearing bed (copper carbonate stains characterize the Milan member limestones). This suggests that the insect-bearing bed at this locality lies stratigraphically very close to the Milan member. Field observations lend support to this supposition. There are thus two possible interpretations: (i) If the stained limestone is part of the Milan member, then the insect-bearing bed is between 682 and 700 feet above the Herington (that is, thickness of Milan is 8 feet plus 10 feet interval to top of YIB, equals 682 feet); (ii) if it is not part of the Milan member, then