and that the sediment consisted of equal amounts of calcite and dolomite. The precipitation is believed to be due to elevated *p*H of the waters caused by photosynthesis of the aquatic plants. This would certainly produce wide local variations, and undoubtedly conditions suitable for precipitation of carbonate minerals would be fortuitous rather than usual. The phenomenon certainly does not occur every day during the plant growth period, and indeed in some years—for example, 1957, an extremely dry year—no precipitation would occur at all.

Nevertheless, a calculation can be made from the value for suspended sediment if we make some assumptions, and the value thus derived agrees quite well with the values already given. If we assume a density of the compacted sediment of 2.5 g/cm^3 (about 10 percent less than the density of the pure solid phases), a mean water depth of 50 cm, and precipitation on 5 days annually, we find that the sediment will accumulate at a rate of 0.5 mm/yr, with an uncertainty of ± 0.5 mm for any particular year. Since the area is under study, there is reason to hope that more precise data will be available in the future, but we feel that the range 0.2 to 0.5 mm/yr can be accepted with confidence as a realistic estimate of the rate of accumulation of these carbonate sediments.

As pointed out by Deffeyes and Martin (*6*), textural evidence that some carbonates may be Recent may be invalid, and all such carbonates should be analyzed by the carbon-14 method. The measurements given here prove unequivocally that the carbonates reported are Modern, and they support the suggestion (*1*) that these carbonates are still forming today.

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1 November 1962

Self-Maintained Visual Stimulation in Monkeys after Long-Term Visual Deprivation

Abstract. *Newborn monkeys reared in darkness for 16 months, except for daily 1-hour periods of exposure to unpatterned light, were allowed to press a lever to obtain unpatterned light. The animals showed apparently insatiable responding, at rates that were extremely high as compared with rates for normally reared control animals.*

It was established in an earlier study (*1*) that the amount of visual stimulation a monkey will give itself is a function of the duration of deprivation from light just prior to the test period. At the same time it was suggested that the response rate is also a function of the long-term level of visual input from the environment. In the study reported here, monkeys with very different histories of exposure to visual stimulation were compared with respect to their rates of self-maintained visual stimulation after deprivation from light of fixed duration immediately prior to the test.

Within the first month of life two monkeys [one a *Macaca mulatta,* one a *Macaca irus* (a cynomolgus)] were taken from their mothers and maintained separately in totally dark air-conditioned boxes that were partially sound-proof and large enough to allow adequate exercise (*2*). These boxes were located in a light-tight room; bottle feeding, handling, and feeding with solid foods were carried out in total darkness or with the animal's face effectively masked. To prevent retinal degeneration and blindness (*3*) the monkeys were exposed to diffuse unpatterned light for 1 hour daily, as follows. Each animal was removed from the living quarters in total darkness and seated in a restraining chair. Its neck was placed in a horizontal pillory which restrained the head comfortably and prevented the admission of light from below. Two domes of frosted Lucite, placed one inside the other, were positioned over the head of the animal so as to admit only unpatterned light from an incandescent light source housed in a chamber which covered the top of the chair. After this daily 1-hour exposure to light the monkeys were returned to the dark living quarters. The control animals were two monkeys (one a *Macaca mulatta,* the other a *Macaca irus*), of the same age as the experimental animals, that had been raised normally.

After 16 months under these conditions a phase of daily test sessions was initiated in which the rate of self-maintained visual stimulation was measured for both groups. Each animal was placed in a restraining chair and allowed to press a lever with its hands. Each lever press produced light for 1 second inside the chamber above the translucent domes. The duration of the light was independent of the duration of the initiating lever press, and independent of lever presses made while the light was on. Two measures were recorded: (i) the total number of responses (lever presses) and (ii) the total number of illuminations. In this way it was possible to determine the total duration of light produced by the animal and to obtain some general index of the monkey's motivational state as measured by the total number of responses. The test session for each experimental animal was terminated when the monkey had produced light of total duration of 1 hour. The regimen established during the first 16 months of life was thereby maintained. In order that the control animals and the experimental animals should experience equivalent periods of visual deprivation in each 24-hour period immediately prior to the test session, the control animals were caged in totally dark living quarters, when they were not in the test apparatus, during the phase of test sessions. The test session for the control animals was arbitrarily fixed at 2 hours. Thus, both the experimental and the control animals were maintained in darkness for at least 22 hours each day during the phase of test sessions. All the animals were tested daily, with the exception of occasional missed days distributed randomly throughout the 19 weeks of the study.

Within the first week of test sessions the animals that had been raised in darkness showed rates of response strikingly higher than even the highest rates for the control animals of this or the earlier study (*1*). In the second week of test sessions the average response rate for the two experimental animals had risen to 3400 and 2350 responses per hour, respectively, as compared with averages of 100 per hour for the two controls. The dark-reared animals maintained this high rate of response consistently in test sessions extending over a period of nearly 5 months;

there was no indication of a decline in response rate during this period. By contrast, response rates for the control animals were never higher than about 500 responses per hour, even after these animals had been maintained in continuous darkness, except during the test sessions, for 9 weeks (*4*). Comparable differences between results for the experimental and the control animals were also seen when the total number of illuminations per hour was taken as a measure of response.

One might raise the question, Was the response rate in fact maintained by the visual stimulation which followed each lever press or was it maintained by kinesthetic or auditory stimulation produced by the act of manipulating the lever? To answer this question, different experimental conditions were established: from week 7 to week 10 the daily test session for the experimental animals consisted of a continuous session divided into three periods. The initial period was a 1-hour extinction period during which the monkeys had access to the lever as usual but a lever press did not turn on the light. During the second period the animals were allowed to press the lever freely and each lever press produced light, as in the test sessions for weeks 1 to 6. After the animals had pressed the lever enough times to produce a total of 30 minutes of light, the light was automatically turned on and remained on continuously for a period of 30 minutes—the third and final period of the test session. On this regimen each experimental animal continued to receive daily a total of 1 hour of light.

Under these conditions the experimental animals quickly became quite sophisticated, and extinction of lever pressing was rapid during the initial, dark period of each test session, the rate for each experimental animal being about 200 responses per hour. Response rates were equally low when the light was continuous, during the final period of the test session. By contrast, the experimental animals responded at rates of between 2000 and 3000 responses per hour during the second period of the test session. Thus, the experimental animals responded at very low rates when lever pressing did not produce light, or when the light was already present, but at very high rates when lever pressing produced light.

From weeks 10 to 19 the experimental animals were placed on a schedule of 6-hour daily test sessions, in order that the effect of long test sessions on the response rates might be studied. It was found that response rates declined only about 15 percent from hour 1 to hour 6 of the test sessions for the *Macaca mulatta* and less for the *M. irus* (see Fig. 1). Furthermore, there was no evidence of a decline in response rates during this 10-week period, average rates of response having been approximately as high on week 19 as on week 10. The observation that the light-deprived animals pressed the lever for light at rates of 2000 to 3000 presses per hour for 6 continuous hours daily over a period of 10 weeks afforded a striking demonstration of the insatiable character of the behavior.

It should be emphasized that the experimental animals did not differ in spontaneous behavior, except in their high rates for response light, or in physical development from the normal controls. Since the experimental design prevented assessment of factors such as isolation from other animals and reduced auditory stimulus, we cannot be certain that light deprivation was the essential factor in producing the high rates of self-maintained visual stimulation, although this seems highly likely. It does appear that an animal's previous visual experience is an important determinant of his later need for visual stimulation, but it is not yet known whether visual deprivation occurring early in an animal's life and deprivation occurring late in its life are equally effective in producing the behavior described.

Although studies of normal animals have revealed regulation by the animal of visual input (*1*, *5*), the relationship of the phenomenon described here to the many findings on sensory restriction reported in the literature is not clear. The persistent electrophysiological changes reported by Fourment and her co-workers (*6*) for rabbits exposed to long-term super- or subnormal illumination may be relevant, indicating underlying neural mechanisms.

We conclude that the effects of short-term experimental sensory deprivation

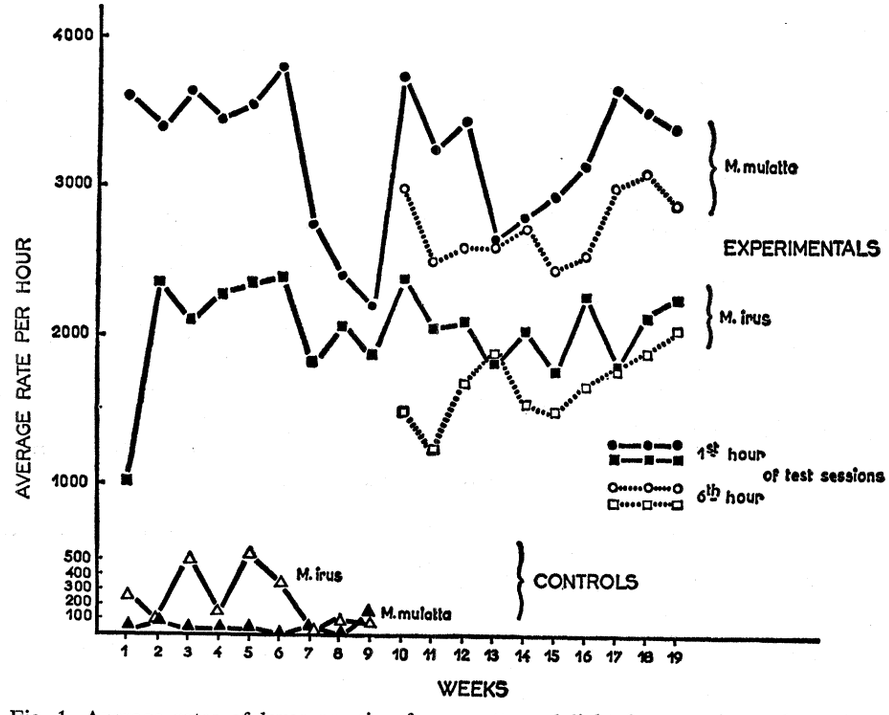

Fig. 1. Average rates of lever pressing for unpatterned light for experimental monkeys and for normal control monkeys during 19 weeks of test sessions. The points joined by solid lines represent the average number of lever presses produced by the animal during the first hour of its test sessions for the week indicated. The points joined by dotted lines for the experimental animals (weeks 10 to 19) represent the average number of lever presses produced by the animal during hour 6 of its test sessions for the week indicated. Data presented for the experimental animals for weeks 7 to 9 are rates for the second period only of the test sessions; rates during the initial, extinction period were excluded from the calculation.

cannot be isolated from the total sensory history of the animal. The basic question of the origin of the apparently insatiable responding for light, at extremely high rates, will remain unanswered until extensive developmental studies are undertaken (*7*).

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4. A third experimental animal (*M. mulatta*), which was subjected to visual deprivation for a shorter period, showed a similar but less marked elevation of response rates. Testing of this animal was begun after 15 weeks of visual deprivation, when the monkey was 4 months old. Its rate of responding for light (1500 to 2000 responses per hour for weeks 2 to 8 of testing) was significantly higher than that of its normal control of the same age, yet lower than the response rates of the other two experimental animals. It is not known whether the intermediate response rate of this experimental animal is related to the shorter period of visual deprivation or due simply to factors of motor development.
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5 December 1962

Growth of the Cellular Slime Mold Polysphondylium pallidum in a Simple Nutrient Medium

A previous attempt to cultivate the slime mold *Dictyostelium discoideum* axenically was successful, but the generation time was too long (16 hours as compared with 3.5 hours in two-membered culture with *Aerobacter aerogenes*) and the stationary-phase cell yield too low (*1*).

Furthermore, the medium was extremely complex and included an undefined lipoprotein fraction from bacteria. A fresh attempt, with the species *Polysphondylium pallidum* (Olive), strain PP-1, has provided a much simpler medium in which exponential growth is achieved, with a cell yield of about 1.5 g (dry weight) of cells per liter.

The constituents of the medium are as follows: lecithin (Glidden Products), 400 to 800 μg/ml; a lipid-free milk powder (Starlac), 0.5 to 2 percent; proteose peptone, 1 percent; and 0.05*M* phosphate at *p*H 6.5 (autoclaved 25 to 30 minutes at 120°C). Aliquots (5 ml) containing an inoculum of 1×10^4 amoebae per milliliter or of spores taken from fruiting bodies were shaken (130 cy/min; 4-cm stroke) in 125-ml erlenmeyer flasks at 23°C. The flasks were covered with aluminum foil to prevent evaporation. Figure 1 shows the kinetic data obtained in three separate subcultures of amoebae. The generation time was 3.7 hours; the yield, 1.6×10^7 cells per milliliter. No lag phase was encountered when the inoculum consisted of amoebae taken from a log-phase culture. Spores and stationary-phase amoebae showed lag phases of varying duration depending on age and physiological state. The milk fraction is not essential; a generation time of about 4.5 hours and a yield of 1.0×10^7 cells per milliliter were obtained when the milk fraction was omitted. Lecithin and at least one of the protein sources are essential. *Polysphondylium pallidum* has been maintained in this medium over the course of seven serial passages (about 100 generations) without loss of rate or yield. Excellent growth and adequate fruiting-body construction are obtained on a corresponding agar medium, in both mass and clonal culture. Two kinds of sterility controls were run. Various dilutions of log-phase cultures were inoculated into nutrient broth, incubated at 30° and 38°C (temperature above the tolerance of the slime-mold amoebae), and plated on lecithin-peptone-milk agar at 24°C. There were no signs of contamination. In any case a yield of 10^7 amoebae per milliliter has been found to require the presence of 10^{10} living bacteria per milliliter (*2*), and contamination at this level would have been detectable by simple microscopic inspection.

Neither *Dictyostelium discoideum* nor *Dictyostelium mucoroides* could be cultivated in the medium described here (*3*).

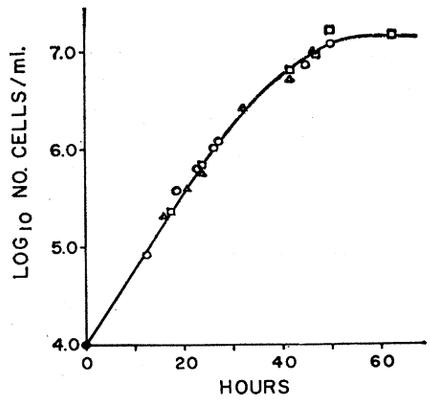

Fig. 1. Kinetic data obtained in three separate subcultures of amoebae.

Note. The successful axenic cultivation of *P. pallidum* was reported in an abstract [H. Hohl and K. B. Raper, "Abstracts of Papers Presented at the Second Annual Meeting of the American Society for Cell Biology" (Nov. 1962)] which appeared after this report had been submitted for publication. The medium used by Hohl and Raper contains bovine embryo extract, bovine serum albumin, Tryptose, dextrose, vitamins, and inorganic salts. The culture used in our study was derived from *P. pallidum*, strain WS-320, obtained from Raper's laboratory in July 1962. This, interestingly enough, is the strain upon which Hohl and Raper have centered their investigations.

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5 December 1962

Two New Forms of Silicon

Drickamer and Minomura (*1*) have observed that at 25°C the electrical resistivity of silicon drops by a factor of about 10^5 upon compression to about 200 kilobars, and the compressed silicon appears to be metallic. They noted that the pressure interval over which the resistivity changes most rapidly depended upon the amount of