gency was removed. At no time was an exteroceptive stimulus used to signal the presence of either a punishment or punishment-free period. When the unpunished following had once again reached relatively high amounts, the punishment contingency was reinstated. Finally, the punishment contingency was again removed when following had been reduced.

The following behavior of each duckling throughout the experiment is summarized in Fig. 1. Since the stimulus was present for varying durations during punishment periods (depending upon how many punished following responses occurred), direct comparisons of response frequency during the several periods are inappropriate. Accordingly, a relative measure, following responses per opportunity, was calculated by dividing the sessions into units of 1 minute each. The total number of seconds of stimulus presence was determined for each unit. (During the punishment-free periods, of course, the stimulus was always present.) This total divided by the number of seconds required for the stimulus to make a single excursion approximates the number of opportunities for the duckling to pass through the photocell beam, given perfect following. In a given unit the number of following responses per opportunity is the number of times the duckling interrupted the photocell beam divided by the number of opportunities to do so, given perfect following, a ratio having the value of 1.0 for perfect following and 0.0 for no following responses. With this procedure it is possible to have a high ratio with only a few seconds' duration of stimulus presence, if the duckling began to follow immediately when the stimulus reappeared after each 8-second removal. Also shown in Fig. 1 is the total duration of stimulus presence in each unit.

In general, the relation between following responses per opportunity and duration of stimulus presence during punishment is approximately inverse. The lack of a perfect inverse relation is due to the variability of the relative positions of the duckling and the stimulus when the latter reappeared after an 8-second withdrawal.

For all subjects, the overall effect of the punishment contingency was to reduce gradually the tendency to follow, so that by the end of a given punishment period the duckling seldom followed, and the stimulus was almost continuously present (Fig. 1). The tendency to follow, however, never disappeared altogether. Thus, once a given punishment period terminated, and following no longer led to stimulus withdrawal, the ducklings again resumed following. All ducklings were observed throughout the session. Many distress calls were heard during stimulus withdrawal when the ducklings were first exposed to the punishment contingency. Later, however, there were relatively few calls during stimulus withdrawal, and none during stimulus presence even when the ducklings did not follow. No duckling ate or drank during the session, and during punishment periods they usually sat and observed the stimulus from the side of the compartment away from food and water.

For two of the ducklings (Nos. 2 and 4), the transitions to high rates of following during punishment-free periods were abrupt and occurred with the first unpunished following response. This may mean that the events during punishment (that is, stimulus withdrawal) were serving in a discriminatory capacity and the following was only suppressed when the response had recently led to stimulus withdrawal. For the third duckling (No. 14), the effects of the prior punishment contingencies were more lasting, and the tendency to follow increased gradually (rather than abruptly) during punishment-free periods. However, duckling 14 was exposed to the punishment contingency longer than the other two ducklings, and this factor may be responsible for the difference. Whether it is or not, however, the present data make it clear that response-contingent withdrawal of an imprinted stimulus provides an effective procedure for reducing the probability of following behavior.

Of the few previous investigations of punishment by withdrawal of a positive reinforcing stimulus, the study by Baer (5) is most similar to our work. Baer used the withdrawal of opportunity to watch filmed cartoons to reduce the occurrences of a concurrent food-reinforced lever response in children. Although his procedure yielded reliable response decrements, the lever response was fairly weak to begin with, and during the test it was being extinguished. In the present study the punished response was initially quite strong, and no extinction procedures were used. Even so, our findings revealed substantial response decrements attesting to the efficacy of this form of punishment.

Finally, it can be noted that in many studies of imprinting, the subject's manifest tendency to follow an imprinting

stimulus is used as the major index of the degree to which the subject is imprinted (7). Since, however, such behavior is influenced by its consequences (that is, affected by the punishment procedure) it seems possible that when following is used as an index of imprinting, instances in which subjects failed to follow the stimulus may reflect factors other than inadequate imprinting.

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# **Mosaic Numbers**

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Moore (1) finds that the relation

$$= 1.197 \times \left[\frac{1}{\sqrt{5}} \left(\frac{1+\sqrt{5}}{2}\right)^x - \frac{1}{\sqrt{5}} \left(\frac{1-\sqrt{5}}{2}\right)^x\right] \text{ cm}$$

"... yields a set of values for y which fit the observed mid-interval modal values. . . ." He lists the first eleven mosaic units y in sequence: 1.2, 2.4, 3.6, 6.0, 9.6, 15.6, 21.6, 25.1, 40.7, 65.8, and 106.5.

The theoretical implications of Moore's relation should be elucidated. Since each mosaic unit, with the exception of 21.6, can be obtained by adding the two units preceding it, the recurrence relation  $M_{x+2} = M_{x+1} + M_x$ must hold. The best-known numbers which obey this relation are the Fibonacci numbers: these numbers are members of the sequence . . . , 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, . . . and are identified by the symbol  $F_x$  with initial conditions  $F_0 = 0$ ,  $F_1 = 1$ . But there are other such sequences which obey the same recurrence relation; the most prominent of these is the Lucas sequence (2): . . . , 2, 1, 3, 4, 7, 11, 18, 29, 47, . . . identified by the symbol  $L_x$  with initial conditions  $L_0 = 2$ ,  $L_1 =$ 

1. The Fibonacci and Lucas numbers are related, as  $L_x = F_{x+1} + F_{x-1}$ .

Taking the greatest integer in the quotient which results from the division of Moore's mosaic units  $M_x$  by 1.19 (not 1.197 as in Moore's expression) the following sequence is obtained: 1, 2, 3, 5, 8, 13, 18, 21, 34, 55, 89. Clearly these are all Fibonacci numbers except 18 which is a Lucas number (the latter is to be expected, for 21.6 = 15.6+ 6.0).

Moore's investigations (3) are based on close examination of a large number of Roman and Greek mosaics from England, Italy, North Africa, and the Northeast and East Mediterranean, and dating from circa 400 B.C. to about A.D. 530. The procedures of ancient mosaicists, almost completely unknown until recent times, and the thorough inspection of the samples, made Moore arrive at an "Alignment Hypothesis" which in turn led to the derivation of his mosaic units. That the occurrence of Fibonacci numbers in mosaic measurements is curious but not completely surprising is exemplified by the presence of Fibonacci properties in other situations where mathematical relationships of this type were considered unlikely at first; the numerical value of the so-called "golden ratio"

$$\lim_{x \to \infty} (F_{(x+1)}/F_x) = (1 + \sqrt{5})/2 = 1.618034 \dots$$

has been frequently implicated in the numerical proportions of some famous Doric architectural feats such as the Parthenon of Athens. In this context, it will not be unexpected if a ruler such as the one Moore seeks (1) actually turns up.

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- a nonprofit organization with special properties. It is a nonprofit organization with headquarters at San Jose State College, San Jose, Calif.
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- 14 October 1968

14 FEBRUARY 1969

I observed (1) a tendency for mosaic stones packed in rows to align (transversely through the rows) at certain intervals. Patterns would be smoother if mosaicists made them agree with these intervals. Observed alignment intervals coincide (1) with mosaic units, suggesting that this was the reason for mosaic units.

Ledin extracts Fibonacci numbers from mosaic units, and points out that the limit to  $F_x:F_{(x+1)}$  is 1:1.618 [the special ratio known to the ancients in other contexts (2)]. If this was why mosaic units were used, then we have apparently unique (3) evidence that the ancients knew the Fibonacci series, and its connection with 1.618 (4).

I arrived at 1.197 cm as the constant in the generating relation (5) by dividing each observed value by its variable in this relation. Hypothetical values yielded by 1.197 cm fit the observations better than those yielded by either 1.196 cm or 1.198 cm, which diverge roughly symmetrically from the observations. The "odd" unit 21.6 cm can be regarded as  $18 \times 1.197$  cm, but I was unaware of the Lucas series.

Ledin's information raises hope of new light on mosaic units.

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- For example, Euclid, Elements VI def. 3; VI prop. 30. D'A. W. Thompson [Mind 38, 43 (1929)] wrote of the Fibonacci series "... there is no ac-count of it, nor the least allusion to it, in all the history of Greek mathematics..." (p. 50), but suspected (p. 52) that the Greeks knew it because of its simplicity. According to H. S. M. Coxeter, *Introduction* to *Geometry* (Wiley, New York, 1962),
- to Geometry (Wiley, New York, 196 Kepler was first to give the limit to this ra 5. R. E. M. Moore, Science 161, 1358 (1968). rk, 1962), this ratio.
- 2 December 1968

# Hypothalamic Stimulation of **Growth Hormone Secretion**

The significant increase of plasma growth hormone produced by stimulation of the ventromedial nucleus of the hypothalamus led Frohman and his colleagues (1) to propose that the hypothalamic control of growth hormone secretion resides in the ventromedial nucleus. This is an unfortunate interpretation because it raises the specter of the "neural center" concept for the hypothalamic control of growth hormone secretion. We believe this is wrong for two reasons:

1) Frohman et al. have not excluded the effects of their lesions or stimulations on fibers which pass through the area of the ventromedial nucleus and which originate from cells beyond that nucleus.

2) We have recently reported growth hormone release from hypothalamic stimulation in the conscious monkey (2) and our three stimulus sites were 4 to 5 mm from the ventromedial nucleus. Under our experimental conditions, current did not spread more than 1 mm. GERARD P. SMITH

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8 November 1968

We have proposed that the ventromedial hypothalamic nucleus is an important locus in the control of growth hormone secretion in the rat. As evidence, we have cited experiments demonstrating decreased pituitary and plasma growth hormone levels after destruction and increased plasma levels after stimulation of this locus. Although limited stimulations in areas just dorsal and lateral to the ventromedial nucleus have not resulted in elevated plasma growth hormone levels, it is possible that other hypothalamic areas may influence growth hormone secretion either through the ventromedial nucleus or independently. We would caution the interpretation of plasma growth hormone rises following brain stimulation in conscious but restrained monkeys. In contrast to the rat, where stress decreases plasma growth hormone levels (1), monkeys tend to respond to various nonspecific stimuli with elevations of plasma growth hormone (2).

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