the system with V_w constant. Commuting the mixed partial and representing the last term in Eq. 5 by r, we write

$$r = (p - u_a) \times [\partial/\partial V_w \, (\partial V_b/\partial p)_{V_w, u_a, T}]_{p, u_a, T} \quad (6)$$

The mixed partial represents, physically, the rate of variation of the coefficient of compression of the soil $\partial V_b/\partial p$ with changing water content. By substitution, Eq. 5 may be rewritten

$$\alpha = n + r. \quad (7)$$

Evidently the pressure coefficient is determined, not only by the shrinkage slope n, as claimed by Croney *et al.* (*1*), but also by the quantity r defined by Eq. 6.

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15 December 1961

Very Small Diatoms: Preliminary Notes and Description of Chaetoceros galvestonensis

Abstract. Several species and genera of very small diatoms have been isolated from Gulf of Mexico waters at Galveston. A quantitative and qualitative study of their distribution has not yet been made. The organisms were isolated in unialgal cultures, and very rapid growth rates were observed. Environmental and experimental implications are pointed out. A new species, *Chaetoceros galvestonensis*, 1.5 by 3.0 microns in broad view, is described and figured.

During experimental studies on filterable organisms isolated from surface waters of the Gulf of Mexico, several species and genera of unusually small diatoms have been found. Whatman No. 52 paper was used for the filtration. One species of *Chaetoceros* measured 1.5 microns on the apical axis and 3 microns on the pervalvar axis. Other genera have been collected with individual cells as small as 0.75 micron in diameter and forming spiraled and straight chains (the extreme range for most diatoms hitherto reported is from 10 to 200 microns). All of the diatoms appear to be normal, with well-developed chromatophores, nuclei, pyrenoid bodies, and oil globules. The various types have been isolated as unialgal cultures in standard culture media originally formulated for certain dinoflagellates. They proliferate profusely and subculture readily. In the case of several species an inoculum of 0.1 ml introduced into 10 ml of culture medium produced homogenous turbidity in less than 48 hours, and by the end of the fourth day the diatoms were forming green deposits in the bottoms of the tubes. Morphological observations were made with the aid of phase microscopy at a magnification of 1250.

Efforts to learn more about the nutritional requirements and the effects of physical factors on growth rates are being made at the present time. One example of these organisms is described below as a new species, and other descriptive material is being prepared.

The existence of populations of such small organisms in the environment and in experimental work may be significant. The small size and consequent high surface-to-volume ratio of these cells, together with their capability for rapid multiplication, have two important, closely related implications for the oceanographer. First, these factors might enable the diatoms to reproduce rapidly even under conditions of minimal nutrient concentration; and second, because of their power of intense utilization of nutrients, they might cause a very rapid depletion of an adequate concentration of nutrients.

In addition, these cells might have effects on light scattering, sound scattering, and heat absorption; because of the large amount of metabolic and degradative organic residues produced, their effect on viscosity and surface tension of the water certainly needs investigation.

Their importance as possible contaminants in light and dark bottles is obvious to those who are studying marine productivity by gasometric methods. Their minuteness and their failure to respond to bacterial sterility tests make it possible for them to be present as contaminants in unialgal cultures of larger diatoms and dinoflagellates. Our experience indicates that they will multiply over a wide range of temperatures (2° to 25°C).

Because their size approaches that of bacteria it is possible that very small diatoms offer a new approach to problems in the nutrition of filter-feeding organisms such as oysters, mussels, and certain adult and immature crustaceans that feed on plankton.

It is impossible to estimate the quantitative aspects of these implications in the open sea until some method for measuring the density of the organisms can be developed. This may be difficult to do because of lack of methods for separating such small organisms from larger diatoms, protozoa, and other plankton. Meanwhile we hope to gain insight into their potential importance by experimental procedures.

Chaetoceros galvestonensis sp. n. (Fig. 1).

Cells solitary. Apical axis 1.5 microns, pervalvar axis 3 microns. Broad girdle view rectangular with valve surface slightly convex. Valve view ellipsoidal; a bristle located at each corner of broad girdle view; bristles about 2 microns long, comparatively thick. Two large L-shaped chromatophores, one at each end of frustule; large pyrenoid body subject to pronounced brownian movement. Resting spores not observed. Cells quite uniform in dense culture material. Isolated from surface water outside of surf line, Galveston Beach. Specific name for Galveston Island, site of first location (*1*).

Chaetoceros galvestonensis sp. n. (Fig. 1).

Cellulae solitariae. Axis apicalis 1.5 micra, pervalvaris 3 micra. Aspectus lato-zonalis rectangularis facie valvari subconvexa, in quoque angulo setifer setis longitudine ca. 2 micra sat crassis.

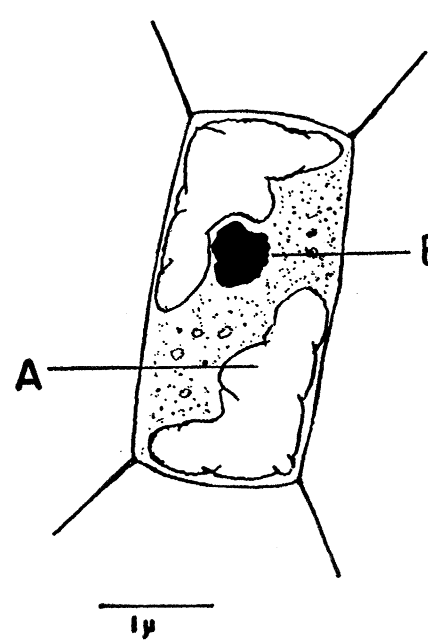

Fig. 1. *Chaetoceros galvestonensis*. *A*, chromatophores; *B*, pyrenoid body.

Aspectus valvaris ellipsoidalis. In quoque apice frustulae chromatophorae duae magnae L-formes. Corpus magnum pyrenoideum agitationem brownianam argute exhibens. Sporae dormientes non visae (*2*).

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Notes

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2. We gratefully acknowledge the courtesy of Dr. Lloyd H. Shinners, director of Herbarium, Southern Methodist University, in providing the Latin translation of the technical description of *Chaetoceros galvestonensis*.

2 April 1962

Intermittent Reinforcement by Removal of a Conditioned Aversive Stimulus

Abstract. Brief electric shocks were delivered at irregular time intervals but only while a light was on. A response was reinforced on a ratio schedule by the termination of the light. This method produced a high rate of response quite similar to that produced by a comparable schedule of food reinforcement.

An organism will maintain high levels of performance when positive reinforcement, such as food, is delivered only intermittently (*1*). In the method described here, intermittent reinforcement involving an aversive stimulus (electric shock) rather than food is used to maintain behavior.

Five squirrel monkeys were subjects. In the first phase of the procedure a brief (0.3-second) electric shock was delivered to the monkeys through a floor grid at irregular intervals of time as long as the experimental chamber was illuminated by a dim white light. When the chamber was darkened, no shocks were delivered. In the second phase, the subject could terminate the light (conditioned aversive stimulus) for a period of 2 minutes by pressing a wall-mounted lever. This phase is shown in the left section of Fig. 1. Thus far, the procedure differs from the classical avoidance procedure of Bechterev (*2*) mainly in that the conditioned stimulus can be terminated only by a response. It should be noted that the termination of the light was ineffective as a reinforcer unless the light had been previously paired with the shock.

In the third phase, the number of responses (ratio requirement) necessary to terminate the conditioned stimulus was gradually increased. The subject now had to press the lever several times to remove the conditioned stimulus, as shown in the right section of Fig. 1. These changes in the ratio requirement produced characteristic changes in the frequency, as well as in the temporal pattern of responding (Fig. 2). At ratio requirements less than 50 responses, the subject began to press the lever almost as soon as the light appeared. The subject maintained a high rate of approximately four responses per second until the light was turned off. At ratio requirements up to five responses, only one or two shocks were delivered during each 6-hour session since the light was turned off within a few seconds after its appearance. As the ratio requirement was increased, little or no responding occurred immediately after the light appeared. This "pause" was as short as a second or so at ratio requirements below 50 and as long as 20 minutes at the ratio requirement of 350 responses. After each pause, the subject abruptly began to respond at a high rate and maintained this rate until the light was turned off. Similar changes in responding have been found when a response ratio terminated an unconditioned, rather than a conditioned aversive stimulus (*3*). On the other hand, a ratio requirement did not produce this pattern of "pauses" and "runs" when no stimulus change resulted at the completion of the ratio (*4*). Fixed-ratio reinforcement has been demonstrated recently by Sidman (*5*) when the reinforcement consists of escape from an avoidance situation.

At the low ratio requirements, the animal pressed the lever at such a high rate that there was never more than a small fraction of a second between any two responses (see Fig. 2). When shocks occurred, they were necessarily within a fraction of a second after a response. In spite of this virtual punishment of individual responses, the subject continued to respond at a high rate. Therefore, the removal of the stimulus associated with shock appeared to be the primary source of reinforcement; the immediate relation of the shock to the responses appeared to be distinctly secondary in maintaining the behavior. Hence, the present procedure differs from the Sidman avoidance procedure (*6*) in which the primary relationship is between the shocks and the responses.

Once this pattern of behavior is well established, the shocks could be scheduled as infrequently as ten per hour with relatively little loss of behavioral control. Also, there is only a slight reduction of responding when the escape duration is reduced to as little as 30 seconds. Hence, the procedure produces a large amount of behavior with very few electric shocks and very brief escape periods. The results described above were typical of all five subjects studied.

The pattern of responding under this procedure is comparable in every major respect to the pattern of responding that is obtained with fixed-ratio positive reinforcement. Both schedules generate exceptionally high levels of responding. In both procedures, the pattern consists of a pause after reinforcement followed by a high and constant terminal re-

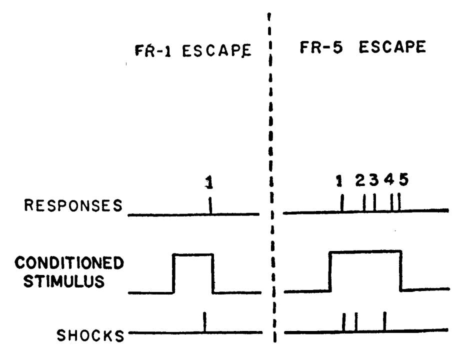

Fig. 1. Diagrammatic representation of the experimental procedure (see text).

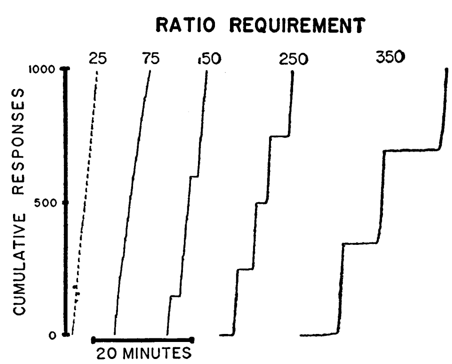

Fig. 2. Escape from conditioned aversive stimulation by one monkey. Each segment is a sample cumulative record of the responses under various ratio requirements. The oblique pips indicate a 2-minute escape period during which time the conditioned aversive stimulus was removed. The recording paper did not move during this interval. Brief shocks (not indicated) were delivered at variable intervals (average: one every 3 minutes) during the conditioned stimulus.