treatments with each chemical 72 hours after inoculation of the plants or by soil treatment at planting time and subsequent inoculation of the bean foliage with uredospores.

Both materials were tested in the field for their effect against loose smut of barley caused by *Ustilago nuda*. Barley seed variety 'Larker,' known to be infected with the loose smut fungus, was treated in glass jars with 0.125, 0.25, and 0.5 percent of chemical by weight of the seed. The seeds were planted in the field 8 April 1965 in duplicated 10-meter plots. About 2 months later on 18 June the effect of the seed treatment was noted by counting the smut-infected and the healthy seed heads in each plot (Table 1). In this experiment the sulfide D735 was highly effective in controlling the systemic loose smut disease. The oxidized form F461 was moderately effective.

The above experiment was repeated in the field during the 1965 growing season, and the initial findings were confirmed. None of the plants grown from treated seeds showed any signs of injury at any of the three dosages.

We conclude that 1,4-oxathiin derivatives are a new class of truly systemic fungicides which selectively control plant diseases without adversely affecting the host. Of particular interest is the fact that these chemicals control systemic diseases such as those caused by *Ustilago nuda*.

B. VON SCHMELING
Chemical Division, United States Rubber Company, Bethany 15, Connecticut

MARSHALL KULKA
Research Laboratories, Dominion Rubber Company, Ltd., Guelph, Ontario, Canada

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9 March 1966

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A Permian Productoid Brachiopod: Life History

Abstract. *Spine arrangements on silicified specimens of* Waagenoconcha abichi *(Waagen) from the Khisor Range of West Pakistan suggest that the juvenile shell attached itself to a foreign object, and that the adult shell lay on its ventral valve in the substrate, anchored and stabilized by a dense corona of long slender spines around the ventral visceral disc.*

The ecology and living habits of many extinct species are difficult to determine because of the absence of critical features in much fossil material. For this reason the life histories of many groups of fossil brachiopods have remained matters for speculation. Recently, however, intensive searches for silicified shells, and large-scale programs of etching them from limestone, have begun to produce specimens of sufficiently high quality that the living habits of some of these ancient forms can be interpreted more confidently.

The productoid brachiopod *Waagenoconcha abichi* (Waagen) has been known from the Permian Productus Limestone of the Salt Range, West Pakistan, and of its trans-Indus extension, the Khisor Range, for almost 90 years (*1*), largely on the basis of specimens that had been freed by natural weathering or by cracking of the rock. These specimens exhibit numerous low tubercles, with hollow ends, that were interpreted as the bases of thin recumbent spines (*1, 2*). Noetling's (*3*) illustration of a ventral valve, partly weathered from the rock, showed that some of the spines are long and thin and that at least some are not recumbent but almost perpendicular to the shell surface. The arrangement of spines over most of the shell surface remained unknown, and the living habits of the animal could be deduced only by analogy with other productoids (see *4*).

Several small blocks of argillaceous limestone, showing evidence of silicified brachiopods, were collected from the topmost beds of the Middle Productus Limestone on the west side of a broad valley that opens just north of the village of Kotla Lodhian in the Khisor Range (*5*). Decalcified in hydrochloric acid, these blocks produced many valves and a few complete shells of *W. abichi* having almost all spines intact. The shells provide several lines of evidence that permit interpretation of the life habits of the species.

A few small disarticulated ventral valves retain the spine arrangement of early youth. The indented apex of the beak and the presence of two or three pairs of convergent apical spines imply that the young shell was attached to some foreign object that suspended it above the substrate, or perhaps stabilized it at the level of the substrate. Similar attachment has been reported for the young of several groups of productoids (*2*), and one species is reported to have remained attached by the apex throughout its life (*6*). *Waagenoconcha abichi* was not observed attached to any fossilized object, but the blocks contained silicified specimens of several kinds of bryozoans, many hundreds of sponge spicules, and a few specimens of another kind of spiny productoid, any of which could have provided seats for the settling of larvae and for the attachment of spat. Moreover, the larvae may have attached themselves to some kind of vegetation; marine algae abounded during the Permian (*7*).

Larger juvenile shells have the apical spines broken off; the venter bears regularly spaced, thin, short, surface spines that probably helped to stabilize the shell in the substrate after it had broken free from its earlier attachment (*8*). These delicate spines did not form clusters and were therefore probably easily broken by any disturbance of the shell.

Upon attaining a length of about 20 mm the shell put out a dense brush of spines around the ventral margin, many of which became almost 30 mm long but less than 0.5 mm thick (see cover). The next subsequent one or two laminae of growth also produced dense growths of similar spines that grew downward toward the first group, contributing greatly to the number of spines concentrated at one level and undoubtedly greatly strengthening the cluster (Figs. 1 and 2).

Subsequent growth laminae produced no anchoring spines but instead put out short and delicate spines that grew at an angle dorsally, diverging strongly from the last group of anchoring spines. The abrupt transition from large tubercles, which were the bases of the anchoring spines, to the small tubercles produced by surface spines on the trail, was considered to be a primary distinction of the genus *Waagenoconcha* (*4*), although heretofore the nature and arrangement of the spines themselves were unknown.

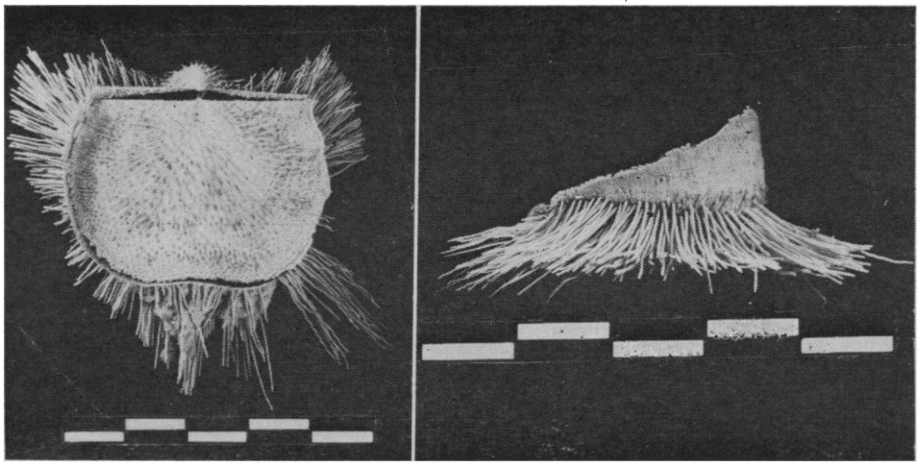

Fig. 1. Two specimens of *Waagenoconcha abichi* from the Productus Limestone of the Khisor Range. (Left) Complete mature shell, showing corona of anchoring spines around ventral valve, and short delicate spines on recessed dorsal valve. (Right) Side view of smaller complete shell, showing uniformity of level of growth of anchoring spines, and short trail with few short spines. Scale, centimeters.

The dorsal valve was nearly flat during youth and bore short delicate spines (Fig. 1). After the ventral valve ceased to produce anchoring spines and the trail began to form, the dorsal valve also bent at the edges to become recessed slightly below the ventral margin. Spines on the dorsal valve remained short and delicate, radiating anteriorly, standing somewhat less than 45 degrees to the valve surface, and pointing toward the margins (Fig. 1).

The adult shell is visualized as having lived with the ventral valve down, anchored and stabilized by the dense corona of spines around the visceral disc. These spines probably acted as a baffle to trap sediment which then banked around the shell, nearly burying it but also helping the spines to keep it stable. The corona of spines also may have had a snowshoe-like effect, keeping the shell from settling too deeply into soft ooze. Sediment probably banked around the trail, which then had to extend upward to keep ahead of sedimentation. The shallow cup of the dorsal valve, with delicate spines, probably also trapped sediment, so that the shell was essentially buried, with only the margin at or slightly above the substrate (Fig. 2). A strong set of diductor muscles, attached to the stout cardinal process (*8*), provided sufficient strength to open the shell against the load of sediment on the dorsal valve. The short surface spines and the thin layer of sediment probably served to camouflage the shell and to prevent the settling of foreign organisms.

It has been suggested that productoid brachiopods rested with the ventral valve upward, the trail and recessed dorsal valve providing space for the gape in that position (*9*). Recent opinion (*2, 4*) holds it more likely that the shell rested on the ventral valve. The Khisor Range specimens provide the following evidence that this was the preferred orientation:

1) Decalcification of two limestone blocks of known orientation produced only one complete shell that was in other than the inferred living position, and that shell was standing vertically on its beak as though it had been disturbed.

2) In contrast, disarticulated single valves were oriented randomly, many with the venter upward and many with spines broken.

3) One block contained a recumbent colony of the bryozoan *Thamniscus*, with delicate growing tips of branches intact, suggesting that it had been buried without having been moved. The zooecia all opened from one side of the colony, facing in the same direction as the dorsal valves of complete shells of *W. abichi*, implying that this direction was upward—away from the substrate.

4) Cross sections of unetched complete shells show bedded mudstone in the ventral valve, with sparry calcite in the apex of the beak and in a layer just under the dorsal valve, indicating that the shell almost completely filled with mud after death of the animal, leaving a small void at the top in which spar later precipitated. That the void was under the dorsal valve indicates that the dorsal valve was uppermost; the complete shell with articulated valves suggests that it was not disturbed soon after death.

5) Several complete shells that were etched free in acid had siliceous mud in the ventral valves, and voids of varying sizes under the dorsal valves where the calcite had been removed.

6) The position of maximum stability of a current-deposited shell is with the convex surface upward (*10*). Geopetal accumulations of mud in *W.*

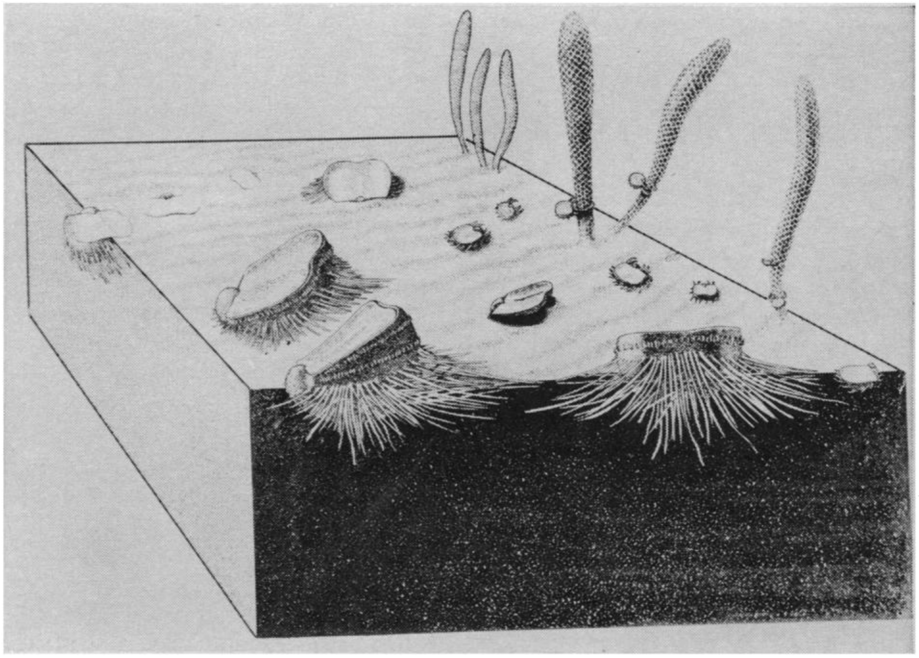

Fig. 2. Reconstruction of auteocoloy of *Waagenoconcha abichi*: spat attached to idealized algae, juveniles lying on substrate, adults in various stages of burial.

abichi indicate that the convex ventral valve was downward, implying that this was the living position—not merely the final resting position of a disturbed shell.

7) The edges of the two valves are coincident; the edge of the recessed dorsal valve extends to the edge of the trail of the ventral valve, providing no space for gape in the inverted position.

8) The side view (Fig. 1) shows the anchoring spines curving to a common level that would have provided stability in the inferred living position, but neither stability nor mutual strengthening in the inverted position.

RICHARD E. GRANT
U.S. Geological Survey,
Washington, D.C.

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17 November 1965

Circadian Rhythms in Rats: Effects of Random Lighting

Abstract. *Increase in body weight, spontaneous running activity, and adrenal cortical function have been studied in rats exposed to a random lighting schedule. In two separate experiments, grouped control animals were given 12 or 14 hours of light alternating with 12 or 10 hours of darkness, respectively, while corresponding grouped experimental animals were given the same total amounts of light and darkness per 24 hour period in a randomized pattern. Random light for periods of 17 to 40 days exerted no influence on growth rate, on weights of endocrine organs, or on adrenal response to adrenocorticotrophic hormone. However, the physiological fluctuation of group running activity and adrenal steroid secretion was abolished. Group desynchronization and the development of circadian rhythms having periods both shorter and longer than 24 hours appear to have replaced the synchronized group rhythmicity.*

Although numerous studies have appeared over the last 30 years on the ubiquity of circadian rhythms in plant and animal physiology and the effects of variations in environmental parameters on these rhythms, investigators generally have given little attention to the question of whether maintenance of these rhythms is essential in the overall homeostasis of the animal. Tentative evidence for such a requirement has come from studies of plant growth (*1*) and experiments with insectivora (*2*). The importance of these rhythms in mammals, however, has not been studied extensively.

In the past, many studies of circadian rhythms have involved the observation and analysis of physiological rhythms under constant environmental conditions. It is known that, with photoperiods of 12 hours of light alternating with 12 hours of darkness, for example, physiological rhythms in mammals tend to display a precise synchrony with the environmental lighting schedule; that under continuous light, period lengths will become shorter in diurnal, and longer in nocturnal, mammals; and that under continuous darkness the opposite will occur (*3*). However, constancy of the environment is only one of the possible modifications that can be used to study circadian rhythms. Another method, and one which to our knowledge had not been investigated, is a randomization of lighting conditions in which periods of light and darkness follow each other at irregular intervals. This experimental design provides control and experimental animals with the identical amount of light per day (that is, an equivalent net photoperiod), and yet prevents the acquisition of rhythmic light information by the experimental group. We now describe a study of locomotor activity, pituitary-adrenal function, and body growth in rats maintained in such a randomized lighting environment.

A large wooden cabinet was constructed having two cages (40 by 70 by 60 cm) on each side; the cages were separated in the middle by an insulated compartment of 30 cm containing an exhaust fan to provide ventilation through each compartment and to mask sound transmission between cages. Two groups of ten male rats (Sprague-Dawley), selected at random from a group of 20 rats of equal age and weight, were separated into the two cages, with food and water being supplied to the animals as desired.

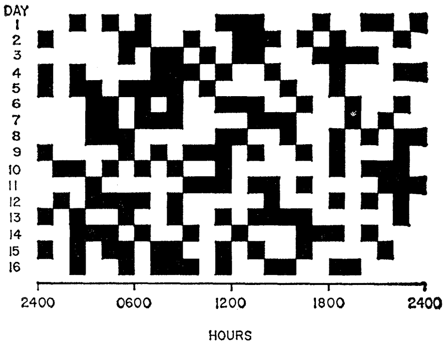

Fig. 1. Daily lighting schedule for experimental rats. Daily totals are 14 hours of light and 10 hours of darkness. Shaded areas represent periods of darkness.

In the first experiment, the control group was subjected to 12 hours of light from 0600 to 1800 hours and 12 hours of darkness from 1800 to 0600 hours. The experimental group also received 12 hours of light and 12 hours of darkness, but in a randomized pattern throughout the 24-hour period. A random pattern of light and darkness, similar to that shown in Fig. 1, was prepared from random number tables and used throughout the experiment. The animals were weighed twice during the first week and weekly thereafter. Locomotor activity was recorded continuously for each group by means of a running wheel (40 cm in diameter) in each cage as well as by transduced measurements of floor screen movements. On the 41st day of the experiment, the rats were decapitated, and the thyroids, pituitaries, adrenals, and testes were recovered and weighed.

In a second experiment, 100 male rats of the same strain, age, and weight as in the first experiment were divided at random into two groups, housed two per cage, and given food and water as desired. The control group was subjected to 14 hours of light, from 0600 to 2000 hours, and 10 hours of darkness, from 2000 to 0600. The experimental group, kept in a similar room next to that of the control group, received an equivalent 14 hours of light, but divided into periods se-