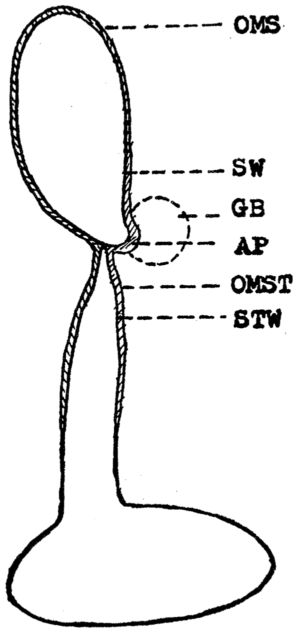

Fig. 1. Diagram of a cell of *Sporobolomyces* producing a sporogenous hypha with ballistospore. (*OMS*, outer spore membrane; *SW*, inner wall of spore; *GB*, gas bubble; *AP*, apicular region; *OMST*, outer membrane of sterigma; *STW*, inner wall of sterigma; the gaseous layer is cross-hatched).

the sporogenous system, even though no bubble is formed.

Several abnormalities that have been observed offer the best evidence that the swelling at the apiculus is a gas bubble and not a liquid droplet. In one instance a bubble burst and knocked the whole spore apparatus over onto the agar surface without causing discharge. On another occasion, as a spore was discharged from one sporogenous hypha, the explosion of the bubble was sufficient to dislodge a nearby spore from its sporogenous hypha and cause it to lodge on the inverted agar surface of a van Tieghem cell culture. No bubble formed on the latter spore before discharge. Quite frequently, under the very humid conditions prevalent in our cultures, the apicular bubble fails to appear altogether, but the entire outer membrane of the spore, probably weakened by excessive humidity, expands at once and envelops the whole spore. This large bubble may eventually burst and dislodge the spore, or it may continue to expand and even envelop one or more nearby spores. On one occasion, an apicular bubble appeared but suddenly deflated like a balloon as the entire outer membrane of the spore expanded. Buller observed these large bubbles but again mistook them for liquid droplets, an assumption which made it especially difficult to explain spore discharge in such cases.

The size of the bubble that is formed around the spore when the whole outer membrane expands indicates that, when the relatively small bubble bursts in normal discharge, there must be sufficient gas left inside the spore apparatus to exert some pressure below the spore and thereby contribute to its discharge.

Thin sections of the gills of various agarics, including species of *Russula, Marasmius*, and *Clitocybe*, as well as *Agaricus campestris* f. *bisporus*, were studied in van Tieghem cells. Although the detailed structure of the spore apparatus in these forms was less distinct than in cultures of *Sporobolomyces*, the discharge mechanism was the same, even to the common occurrence of abnormally large bubbles. Such bubbles may enlarge until they envelop all the spores on a basidium. Large bubbles frequently collapse without effecting spore discharge.

In these agarics, too, there appears to be a gaseous layer between inner wall and outer membrane of spore and sterigma. The gas bubble is normally small and develops opposite the apiculus, which is always pointed toward the central axis of the basidium. Typically, the bubble persists for only a few seconds, and when it bursts the spore is discharged. As noted by other investigators, the spores of a basidium (usually four in number) are discharged successively and never simultaneously. The best evidence of the gaseous nature of the bubbles has come from the observation that they sometimes burst without causing spore discharge.

The outer membrane of the spore apparatus has some very interesting properties. When surrounded by air it becomes impervious to the gas that accumulates between it and the inner wall. This property would likewise protect the spore apparatus and the discharged spore from desiccation. When wet, however, the outer membrane apparently permits free passage of the gas, since there is no accumulation of it in submerged cells or portions of sporogenous hyphae in contact with a wet surface (*Sporobolomyces*). Also, the membrane is quite pliable and stretchable, as demonstrated in the development of both normal and abnormal bubbles.

Since the liquid droplets described by Buller and others were not observed in my study, it seems likely that the earlier investigators mistook gas bubbles for droplets. The bubble discharge mechanism is probably characteristic of all higher basidiomycetes with ballistospores. Since it has also been observed in a mycetozoan, the mechanism should be looked for elsewhere. Also, the possibility of discharge without bubble formation but entirely by gas pressure from within the discharge apparatus should not be overlooked.

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References and Notes

1. O. Brefeld, *Botanische Untersuchungen über Schimmelpilze* (Felix, Leipzig, 1877), vol. 3.
2. C. T. Ingold, *Spore Discharge in Land Plants* (Clarendon, Oxford, 1939).
3. A. E. Prince, *Farlowia* **1**, 79 (1943).
4. V. Fayod, *Ann. Sci. Ser. 7* **9**, 271 (1889).
5. A. H. R. Buller, *Researches on Fungi* (Longmans, Green, London, 1909–1924), vols. 1–3.
6. A paper describing this unusual mycetozoan is in preparation.

10 August 1964

Infestation of the Copepod Acartia tonsa with the Stalked Ciliate Zoothamnium

Abstract. *An entire population of the copepod* Acartia tonsa *in the Patuxent River, Maryland, was infested with a stalked protozoan of the genus* Zoothamnium. *Each copepod had 25 to 200 ciliates attached around the appendages. The infestation occurred at the time when* Acartia tonsa *was being replaced as the dominant copepod by* Acartia clausi.

As part of a large-scale ecological investigation of the Patuxent River estuary of the Chesapeake Bay system, periodic zooplankton collections are made with a towed ½-meter No.

Table 1. Average number of copepods per cubic meter and temperature and salinity ranges during period of infestation.

A. tonsa	*A. clausi*	Temp. range (°C)	Salinity range (0/00)
5 March 1964			
13,000	900	2.34–6.12	4.65–14.22
24 March 1964			
8,000	7,800	8.06–8.89	2.0 –12.10
14 April 1964			
980	11,000	10.27–14.10	0.9 –10.3

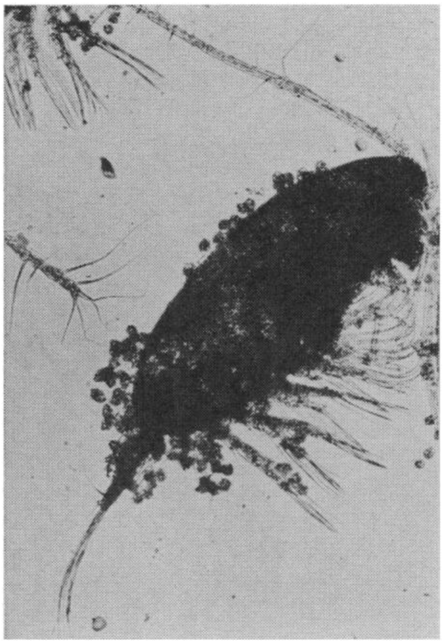

Fig. 1. Infestation of copepods with peritrichous ciliate, *Zoothamnium* sp.

2 net. The copepod *Acartia tonsa* is by far the most numerous zooplankter. Other workers have shown that this copepod is the most abundant species in Chesapeake Bay (*1*), and members of this genus are considered to be the most abundant inshore copepods along the east coast of the United States.

The seasonal cycle of *Acartia* was described by Conover for Long Island Sound (*2*) where *A. tonsa* was dominant from the summer through late winter and was replaced in dominance during early spring by *A. clausi*.

In the Patuxent River in 1963–64, *A. tonsa* dominated the zooplankton population from May 1963 through March 1964 and was replaced by *A. clausi* in late March and April 1964.

During early March 1964, all specimens of *A. tonsa* along the entire river became infested with a peritrichous ciliate identified as a member of the genus *Zoothamnium* (*3*). Each copepod had from 25 to 200 of these stalked protozoans present mainly around the appendages (Fig. 1). *Acartia clausi*, which was present in smaller numbers, was not infested nor were other zooplankters. By late March *A. clausi* and *A. tonsa* were equally abundant; and all *A. tonsa* were infested while only a few *A. clausi* had attached ciliates. Mid-April brought further changes; *A. clausi* became the dominant copepod and only a few *A. tonsa* were present. Each *A. tonsa* present was still infested while no *A. clausi* were affected. Table 1 indicates the relative abundance of the two species of copepods and the temperature and salinity ranges during the infestation period.

Partial examination of zooplankton samples from collections made during the spring of 1963 also showed that *Zoothamnium* sp. were present on some *A. tonsa* during March and April (*4*).

It would appear that *Zoothamnium* sp. was highly specific for *A. tonsa*. While there are numerous reports of individual organisms infested with large numbers of different epizoic ciliates, there have been few reports of entire populations being affected in this manner. Conover (*2*) noted that during winter many older stages of *A. tonsa* were host to a stalked protozoan and attributed this association to a steady-state condition of the copepod population due to wintering over.

Without experimenting with live organisms it is not possible to assess the ciliates' effect on the copepods or to account for the high specificity to *A. tonsa*. It is possible to envision the mechanical effect of numerous ciliates on the copepods. Sinking rates of preserved material were 19.2 cm/sec with infested *A. tonsa* and 13.8 cm/sec for noninfested organisms. It is possible that those copepods laden with ciliates were at a disadvantage in the natural environment.

Although other workers (*2, 5*) have suggested temperature or salinity, or both, as being directly or indirectly responsible for the change of copepod species, it would now appear that other factors, such as infestation with protozoans, may be involved with changeover in dominance from *A. tonsa* to *A. clausi*.

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References and Notes

1. C. B. Wilson, *Proc. U.S. Natl. Museum* **80**, 1 (1932); T. E. Bowman, *Chesapeake Sci.* **2**, 206 (1961).
2. R. J. Conover, *Bull. Bingham Oceanogr. Coll.* **15**, 156 (1956).
3. J. O. Corliss, personal communication.
4. Material was supplied through the courtesy of W. R. Dovel, Chesapeake Biological Laboratory, Solomons, Md.
5. G. A. Deevey, *Bull. Bingham Oceanog. Coll.* **17**, 1 (1960); H. P. Jeffries, *Limnol. Oceanog.* **7**, 3 (1962).
6. We thank A. J. McErlean, Chesapeake Biological Laboratory, for his field assistance. Photographic work was done by L. Land and T. Loder, Lehigh University. The project was supported by funds from NSF, GP883, and Maryland Dept. of Water Resources, grant No. 1. Contribution 64-1, Marine Science Center, Lehigh University; contribution 267, Chesapeake Biological Laboratory.

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Inducing Resistance to Freezing and Desiccation in Plants by Decenylsuccinic Acid

Abstract. *Decenylsuccinic acid induces resistance to desiccation, cold, and frost in young bean plants. When decenylsuccinic acid is sprayed on flowering peach, apple, and pear trees, most of the flowers are resistant to a frost of −6°C.*

Resistance to drought and resistance to freezing in plants generally occur together (*1*). Water permeability of roots should affect survival of plants during desiccation. Also, frost resistant cells show more rapid plasmolysis (*1*), and hence evidently have more permeable membranes. Therefore, since compounds are available that will change permeability, their effect upon resistance to desiccation and freezing was measured.

When decenylsuccinic acid [CH_3—$(CH_2)_6$—CH=CH—CH_2—CH(COOH)—CH_2—COOH] penetrates into the lipid layer of the membrane of bean root cells it increases water permeability eightfold at 30°C. Of most significance here, is the fact that permeability becomes only slightly temperature dependent (*2*). These observations of both water permeability and its response to temperature plus the general correlation of drought and frost resistance suggested that decenylsuccinic acid might render plants resistant to both dry and cold weather.

First, the induction of drought hardiness was demonstrated. The roots of bean (*Phaseolus vulgaris*, var. "Bountiful," 14 days old) were placed in $10^{-3}M$ decenylsuccinic acid (*3*) for 2 hours. The roots were subsequently placed in a 10 percent solution of polyethylene glycol (osmotic pressure 1.3 atm) (*4*). This large molecule (molecular weight 20,000) is commonly used as an os-