SINCE *Bacillus thuringiensis*

With the exception of a handful of scientists, the field of insect pathology was not an area of professional specialization until the early 1950's. Since that time, major advancements in knowledge have occurred in the field. One of the most conspicuous was commercialization of the bacterium *Bacillus thuringiensis* ca. 1960 for control of several lepidopterous insects. Many other advances have been made which were not as well announced to entomologists, including the recent commercialization of the 1st insect virus, the nucleopolyhedrosis virus of *Heliothis zea* (Boddie). To some extent an attempt was made to overcome this oversight in communications, when subsection 2 (Biological Control) of Section C (Ecology, Behavior, and Bionomics) of the Entomological Society of America asked us to organize a symposium on insect pathology for the December 1971 Annual Meeting of the Society. Ten subjects were selected: 4 on insect viruses, 3 on protozoa, and 3 on fungi. The decision to publish was taken several months after the meeting, and in the interim the authors of 3 papers had decided not to publish, or had decided to arrange for publication elsewhere. One of these papers has been replaced in the present volume by a discussion of insect poxviruses. The editors wish to thank the authors for their efforts in converting their talks to proper form for publication.

As evidenced by the papers which follow, a significant amount of research in insect pathology is basic in orientation (e.g., comparative virology) and is not directly concerned with pathogens as agents for insect control. Nevertheless, because of residue and insect-resistance problems associated with conventional pesticides, there is a worldwide trend to depend less on chemical insecticides and to integrate insect-pest control measures. Pathogens are recognized as potentially an extremely useful and safe component in an integrated pest-management program. Accordingly, insect control is directly or indirectly one of the objectives of a high percentage of studies with insect pathogens.

Characteristics of Pathogens Useful for Insect Control.—In general, at least 6 major points should be considered in assessing the suitability of a pathogen for insect control (Cameron 1967). The pathogen should (1) show a high degree of specificity for the particular host, (2) be safe for man, other animals, and the crop, (3) show no resistance by the insect pest, (4) be persistent in the field, (5) be easy to apply and (6) be competitive in cost with other control measures. Implied, but not specified, is a final point: (7) the pathogen must be effective in reducing the pest population below its economic threshold.

Field Testing. — In preliminary laboratory tests, many entomogenous microorganisms have appeared promising for insect control. When these microbes were subjected to field tests, however, the expectations frequently were not fulfilled. In many cases, field evaluations of microbial candidates were conducted prematurely. Further preliminary research might have revealed that the total effect of environmental factors on the candidate microbe was sufficiently deleterious to reduce its effectiveness. For example, environmental factors are known to affect host susceptibility as well as virulence, dispersion, and transmission of several pathogens. A thorough knowledge of the effects of the ecological factors on pathogenic microorganisms may allow alterations in the formulation of the pathogen or in timing of application, and thus make it highly effective and competitive with chemical insecticides.

In general, the field of applied insect-microbial ecology has been neglected. Steinhaus (1968) suggested narrowness of training of specialists in the area of applied research and technology as one reason for generally inadequate development of methods for the microbial control of pests. This is a reasonable assumption, since many of the techniques used in the field application of microbials are unaltered application methods used for conventional insecticides. Perhaps new approaches to a technology for field application of insect pathogens are needed. Specific problems posed in the field application of pathogenic microorganisms could be handled best by those who have specialized in these areas of applied research and technology.

Conceptually, entomogenous pathogens can be used in 3 different ways to suppress insect populations (Yendol and Roberts 1970; Roberts and Yendol 1971).

(1) Colonization: the microbial agent is introduced into the pest population, and an attempt is made to establish the microorganism permanently. The principles of epizootiology of infectious diseases should be considered with this method. In the colonization approach, not only may the redistribution of indigenous forms be considered, but also the introductions into disease-free populations of exotic pathogens obtained through foreign exploration. The currently known viruses and fungi probably offer the greatest potential in this approach. Entomogenous viruses are particularly suited because of their host specificity and their ability both to spread rapidly throughout a population and to persist in successive generations.

(2) Microbial insecticides: the principles of application are similar to those used in applying a chemical insecticide. In some instances, repeated applications are necessary. The classical example of this approach is the microbial insecticide, *Bacillus thuringiensis*. This microbial agent is currently being produced by 3 commercial firms in the United States. More recently, the use of viral insecticides is gaining interest among industrial organizations. In most cases, these microbial insecticides fulfill a need where