RELATION OF INSECTS TO HUMAN LIFE AND TO THE SCIENCES.[1]

J. J. DAVIS, Purdue University.

It was recently remarked that a scientist is one who tells us something which everyone knows, in a language which no one understands, this originally being given by a distinguished ecologist as the definition of ecology. It is not my purpose to talk on technical investigations but rather to discuss a general problem that we may better understand the science in which I am interested, the relation it bears to the science which each of you are interested in, and how we may better correlate and utilize our knowledge. I feel certain that if I were more familiar with the general subject which each of you are specializing in I could correlate my own work to better advantage. We are already doing this in the purely agricultural sciences, as I hope to point out later.

It rarely occurs to one that the innumerable little crawling and flying creatures known under such names as bugs, beetles, flies and worms, belong to the dominant order of living creatures. The dominance of insects—"is another way of saying that the number of fixed variations of structure, form, color, and the like, to be found in insects is greater than that presented by all other land animals. By reason of this extraordinary power of variation, and hence of adaptation—of fitness to various conditions and situations—insects are very widely distributed, and are found in a greater variety of places and surroundings than any other class of land animals on the earth. They are able to maintain themselves, in other words, in a greater number of ways and to avail themselves of a larger variety of the resources of the earth than any other animals" (Forbes). Insects "are small, extremely tenacious of life and endowed with such great powers for reproduction and multiplication that the abundance of any particular species responds very rapidly to changes in food supply, or other variable factors in their surroundings" (Brues). We all know that now and then some section of the country is overrun with grasshoppers, that chinch bugs ruin the corn in some regions, that the army worm may appear suddenly and practically denude certain regions of vegetation. These are only conspicuous manifestations of a struggle that goes on everywhere and continually in which insects are always threatening to devastate the earth and we fail to see or recognize the innumerable insects which are ready to show their voracious habits and become destructive should conditions, either weather, methods of farming and the like, or unfavorable conditions for their natural enemies, favor them. We fail to recognize the battles between harmful insects and their natural enemies which are going on everywhere about us; we fail to realize the fact that insects are not only destructive to crops and animals, and are annoying pests, but that they carry innumerable diseases of plants, of animals and of humans, and that because of this latter fact render some parts

[1] Presented at the 1922 meeting. Contribution from the Department of Entomology, Purdue University.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

of the earth uninhabitable to man, while their continued attacks on certain crops makes farming hazardous and in some sections unprofitable.

According to the latest authorities there are 470,000 described species of insects and no less an authority than the late Dr. David Sharp is responsible for the following statement: "The largest insects scarcely exceed in bulk a mouse or a wren, while the smallest are almost imperceptible to the naked eye, and yet the larger part of the animal matter existing on the lands of the globe is in all probability locked up in the forms of insects. Taken as a whole, they are the most successful of all the forms of terrestrial animals". The numbers of insects are beyond computation. Fortunately there are many checks on the increase of insects and probably only a little change in nature's balance of power would be sufficient to make the earth a desert, or as was so aptly put by one eminent scientist "If the insects would quit fighting among themselves, they would overwhelm the whole vertebrate series". In his recent address as retiring president of the American Association for the Advancement of Science, Dr. L. O. Howard emphasized these points in the following words: "Vertebrates, culminating in man, have acquired the bodily structures which, with man guided by the equally acquired intelligence, has enabled him to accomplish the marvels which we see in our daily existence. And, too, the Articulates have in the course of the ages been modified and perfected in their structure and in their biology until their many appendages have become perfect tools adapted in the most complete way to the needs of the species; until their power of existing and of multiplying enormously under the most extraordinary variety of conditions, of subsisting successfully upon an extraordinary variety of food, has become so perfected and their instincts have become so developed that the culminating type, the insects, has become the most powerful rival of the culminating vertebrate type, man".

When we speak of entomology nowadays we usually refer to economic or applied entomology. That we are beginning to realize that insects are among our most important rivals in nature is evidenced by this understanding of entomology and by the additional fact that the war against insects has become a world-wide movement in which the United States leads. In the States the federal government has a large force of workers, the Bureau of Entomology supporting 400 workers, and each state has its corps of expert investigators and every agricultural college its corps of instructors in entomology. In the American Association of Economic Entomologists alone there are nearly 800 members, practically all of whom are working on one or more phases of economic entomology. This development has ccme in the short space of one hundred years and principally in the last quarter of this century. Even as late as the 80's and even later entomology was considered a hobby, and the entomologist held up to ridicule. I recall a story by Dr. Leland O. Howard to the effect that in the fall of 1878, on his way from Ithaca to Washington to accept his first appointment as assistant entomologist in the U. S. Department of Agriculture, he stopped in New York to call on relatives. Among them was his grandmother who was then 78 years old and whose sons were all big merchants and prominent citizens of New York. Dr. Howard reported a very pleasant visit with his grandmother and after he left she is reported to have said, "Leland is a good boy, but I do wish he was not in such a trifling business".

I wish to discuss principally the importance of insects, the developments in insect control and the relation of entomology to other sciences.

We have already pointed out that insects cause enormous losses. The most recent estimates place the annual losses caused by insects in the United States at $2,000,000,000, an amount equal to $20 for every man, woman and child in the States. If we prorate this loss to the farmers and others on whom the burden largely rests the cost per farm or farmer per year would of course be many times this amount. Insects play a part in every phase of life. The direct damage to growing crops is everywhere evident and conspicuous. But we have also the host of insects which attack stored products, those which affect animals, the various annoying pests, and by no means least, those which carry diseases of various kinds—the sucking insects which carry mosaic and other plant diseases, the ticks and lice, which transmit disease among domestic animals, and the various insects which are responsible for the transmission of numerous diseases of man.

In the past fifty years there has been a marked increase in the numbers of insect pests and at the present time there appears to be no lessening of this gradual increase. A common question is, why are insects more abundant than formerly? This is explained in several ways: We may assume that before civilization there was among animals and plants a natural balance which swayed back and forth but which usually balanced fairly evenly. Civilization has brought about unnatural conditions which have interfered with the natural balance and it has been necessary to utilize artificial measures to restore the balance. This interference is due to a number of causes, principal of which are:

1. Extensive and continuous cultivation of the same or related crops, is favorable to insect reproduction by offering unlimited food supplies continuously year after year; for example, the corn root aphis and corn root worm become most severe when corn follows corn, or the various clover pests which attack only legumes and which appear to be increasing in importance.

2. Transfer from native to cultivated hosts, which may have been due to the eradication or reduced supply of the native host or to a greater preference for the cultivated and usually more succulent host. Thus, we have the chinch bug attacking cultivated plants of the grass family, the colorado potato beetle whose native host was the wild Solanum, the curculio which existed only on wild fruits before cultivated varieties were introduced, and one of recent importance to roses in greenhouses, the rose root worm, which at one time attacked only wild species of Rosaceae.

3. Transportation has had much to do with the economic entomology of the United States. More than half of our most destructive

pests are of foreign origin. These are not necessarily pests of prime importance in their native home but brought here and finding favorable breeding places with the absence of their natural enemies they are capable of increasing with scarcely any restriction. Notable examples include the Hessian fly, San Jose scale, Oriental peach moth, currant worm, cabbage maggot, cabbage worm, wheat midge, European corn borer, gypsy and browntail moths, Japanese beetle, cotton boll weevil, pink bollworm and elm leaf beetle. Even within our own country transportation has had a marked influence on the spread of insect pests. Thus the San Jose scale, first introduced into America at San Jose, California, from China, was carried on shipments of nursery stock, across the entire continent to New Jersey, from which place it was soon distributed on plants to many other sections of the country.

4. The reduction of certain insectivorous birds and mammals is no doubt a factor in the abundance of insects. Increase in population, reduction of forests and hunting have had their influence on the numbers of useful birds and mammals.

Insects are grouped from the standpoint of control in several ways. From the point of view of control by insecticides, they are usually grouped according to the type of mouth parts, i. e., those with suctorial and those with mandibulate mouth parts. From the agricultural standpoint it is desirable to class insects as monophagous (restricted to a single host), oligophagous (dependent on several, usually related species of plants), and polyphagous (feeding on many species of plants). Monophagous insects are usually the most uniformly destructive but probably more readily controlled and are usually more amenable to control by good farm practices. These and other groupings are adopted occasionally for specific uses and while arbitrarily arranged they serve a useful purpose.

Before proceeding with a discussion of insect control problems I wish to call attention to the fact that all insects are not harmful. Fortunately many are directly or indirectly beneficial. Of all described insects approximately half or 225,000 are phytophagous, feeding directly upon the tissues of various plants. Of course, only a small percentage of phytophagous insects affect cultivated crops or plants useful to man but even in recent years many which originally attacked only wild hosts have gone over to cultivated crops and we may anticipate increasing numbers of such transfers. Of the remaining 50 per cent, most of which are benefiicial, about 30 to 35 per cent are parasitic or predaceous on other insects, probably 17 per cent are scavengers, a comparatively small number are beneficial as producers—honey-bee and silk worm—and a few, principally bees and similar nectar-feeding species, as pollenizers.

Practically all insect controls are based on our knowledge of the structure, life history and habits of the insect in question. For convenience we may divide methods of control into two main groups and each of these into smaller groups.

I. Natural Controls
   a. Climatic controls
   b. Natural enemies

II. Artificial Controls
- c. Farm practices
- d. Mechanical devices
- e. Insecticides.

I. As a rule natural controls are not at all or are not readily utilizable artificially, although a knowledge of these control factors will enable one to assist the factors which are optimum for minimizing insect troubles.

(a) Climatic control includes all climatic factors having a definite relation to the absence or abundance of this or that insect. These factors include winter conditions, humidity, soil moisture, precipitation, wind and seasonal weather.

(b) Natural enemies are important factors in minimizing insect abundance and not infrequently of suddenly checking insect outbreaks. However, aside from the control by parasites or predators in nature, little has been accomplished. The introduction of parasites of exotic insects accidentally brought into this country is simply an atempt to renew the balance as it occurs in the native home of the insect pest and is a very profitable and desirable activity. Many examples are available. The cottony cushion scale, introduced into California, threatened to wipe out the citrus industry in that state but the introduction of certain lady-bird beetles from Australia checked it and apparently has ever since held the scale pest in thorough control. The parasites and predatory enemies of the browntail and gypsy moths are playing a significant part in holding these pests in check and minimizing spread. The digger wasp parasite introduced into Hawaii has completely subdued certain foreign grub worms which a few years ago threatened to make cane-growing unprofitable. This list of examples could be increased many times. Only recently has much attention been directed toward artificially utilizing these natural enemies.

Under natural enemies are included not only the insects which are parasitic or predaceous on harmful insects but also the many birds and mammals which prey upon insects. We would also include insect diseases which are endemic and epidemic.

II. Artificial controls may be conveniently grouped into three divisions, control by (c) farm practices, (d) mechanical devices and (e) insecticides. At the present time we immediately think of insecticides as the most important of the insect controls. However, too little attention has been given the important subject of farm practices. In the orchard, greenhouse or vegetable garden it is possible to utilize more or less costly insecticide treatments but such is not usually true in the case of general farm crops such as corn, wheat and clover which are grown less intensively and where the cost of spraying might absorb all profits. Here, then, we must usually adopt certain so-called farm practices. Even in the orchard, the vegetable garden and elsewhere, the farm practices—orchard and garden practices—are becoming more and more recognized as factors deserving of more attention.

(c) Control by farm practices refers to the practices which are or may be a part of the ordinary farm operations such as cultivation, rotation, time of sowing or planting, time of harvesting, trap crops, clean culture, plant stimulation and drainage. As a matter of fact, it is true, as a rule, that all farm practices which are useful in preventing insect trouble are good practices regardless of the insect question. Thus, damage by the corn root aphis and corn root worm, two notoriously serious corn pests, is prevented by rotation, i. e., by not growing corn two or three successive years on the same ground—a good agronomic practice. Injury by the Hessian fly is prevented by sowing wheat after the flies issue and disappear, which date happens to be the best date for wheat sowing regardless of the fly. Most species of wireworms inhabit low, poorly drained ground and their occurrence in destructive numbers may be prevented by proper drainage, pre-eminently a good farm practice. We could recount many examples of insect control by farm practices but these few examples will illustrate the importance of this method of preventing insect losses. Even in lines of agriculture other than general farm crops, good practices are becoming more and more important in insect control. In orcharding certain farm practices play an important role in the control of such insects as the curculio. The animal husbandman finds it of greatest importance that he use sanitary measures and keep his animals in prime condition to best overcome the numerous parasites which may infest his stock. Undoubtedly farm practices are becoming more important phases of insect control and we may anticipate their increasing use in years to come.

(b) Mechanical methods, other than equipment used in applying insecticides, are less frequently utilized although we have a few prominent examples. The control of insects by hand picking may be considered a mechanical means and is probably our most primitive method. Our common house screens for which the people of the United States expend perhaps $50,000,000 each year are mechanical controls. A specially built cage-like affair, called the grasshopper-catcher, has been utilized to large advantage in many sections of the country for the control of grasshoppers. Banding trees to protect them from such insects as canker worms is a familiar example. The use of barriers to protect corn from the chinch bugs as they migrate from small grain fields, the use of tarred felt disks to protect cabbage plants from maggots, the various fly protectors used on domestic animals, sticky fly paper and fly traps, are common examples of this method of insect control.

Although the mechanical devices such as are mentioned are apparently simple they involve thorough investigations into the biological principles and the thorough use of scientific facts. The same is true in the case of the general farm practices. The application of the biological and chemical controls themselves explain the scientific principles which must be considered.

(c) Control by insecticides is by far the most generally effective of the artificial insect controls, but it was only within the last half of the nineteenth century that appreciable progress was made. This was due largely to the ignorance and superstitions regarding insects which prevailed. Even as late as the fifteenth and sixteenth centuries the control of insects was a church problem. Literature refers to church trials of insects and their excommunication from the church because of their depredations. The early efforts in protecting crops by use of so-called insecticides, consisted largely in treatments with soot, ashes, lime and a host of other materials. Some of the earlier recommendations included as many as six or a dozen ingredients. A typical formula recommended in 1779, for mealy bugs, was:

Sulphur	8 ounces
Scotch snuff	8 ounces
Hellebore powder	6 ounces
Nux vomica	6 ounces
Soft soap	6 ounces
Cayenne pepper	1 ounce
Tobacco liquor	1 quart
Water, boiling	1 gallon

The author of this recipe was evidently not entirely confident of is effectiveness for he recommends that the plants be washed with the decoction and that the insects be removed while washing.

The real advances in insecticides have been the result of specific insect problems. The Colorado potato beetle and cotton worm brought about the introduction and use of Paris green. The development of arsenate of lead was the result of problems connected with the gypsy and browntail moths. The seriousness of the San Jose scale brought about the development of the miscible oils and lime-sulphur. Other needs have had an influence on the development of insecticides. Thus the need of standardized tobacco extracts has resulted in the manufacture of standard strengths and made available the practical use of this most valuable insecticide. Similarly the poison gases, used during the war, have opened our eyes to their possible utilization.

There is a vast field for the properly fitted chemist for the development of new insecticides and new phases of present day insecticides. There is likewise a large field for the engineer, for the application of insecticides is itself as important a problem as the preparation of insecticides.

We spoke of the relation of entomology, and particualarly economic entomology, to the other branches of science. As Dr. S. A. Forbes has said: "It is when we search for specific reasons for our successes here and our failures there that we are driven to a scrutiny and analysis of controlling conditions of every description, and so find ourselves involved in studies so far outside entomology, commonly so-called, that we are obliged to apply for assistance to the physiologist, and the chemist, and the physicist, and the meteorologist, and the geographer, and the agriculturist, and the animal husbandman, and the bacteriologist, and the physician, and the sanitarian, or in a word, to the ecologist, who from the nature of his studies, must, if he is to thoroughly cover his field, be something of each and all of these and still something more." As is true with every other science the field of entomology is broader than is generally supposed. In the study of insecticides the entomologist must have a thorough knowledge of the science or the assistance of the chemist, the plant physiologist, the horticulturist, and the meteorologist and in development of means of application the services of the engineer

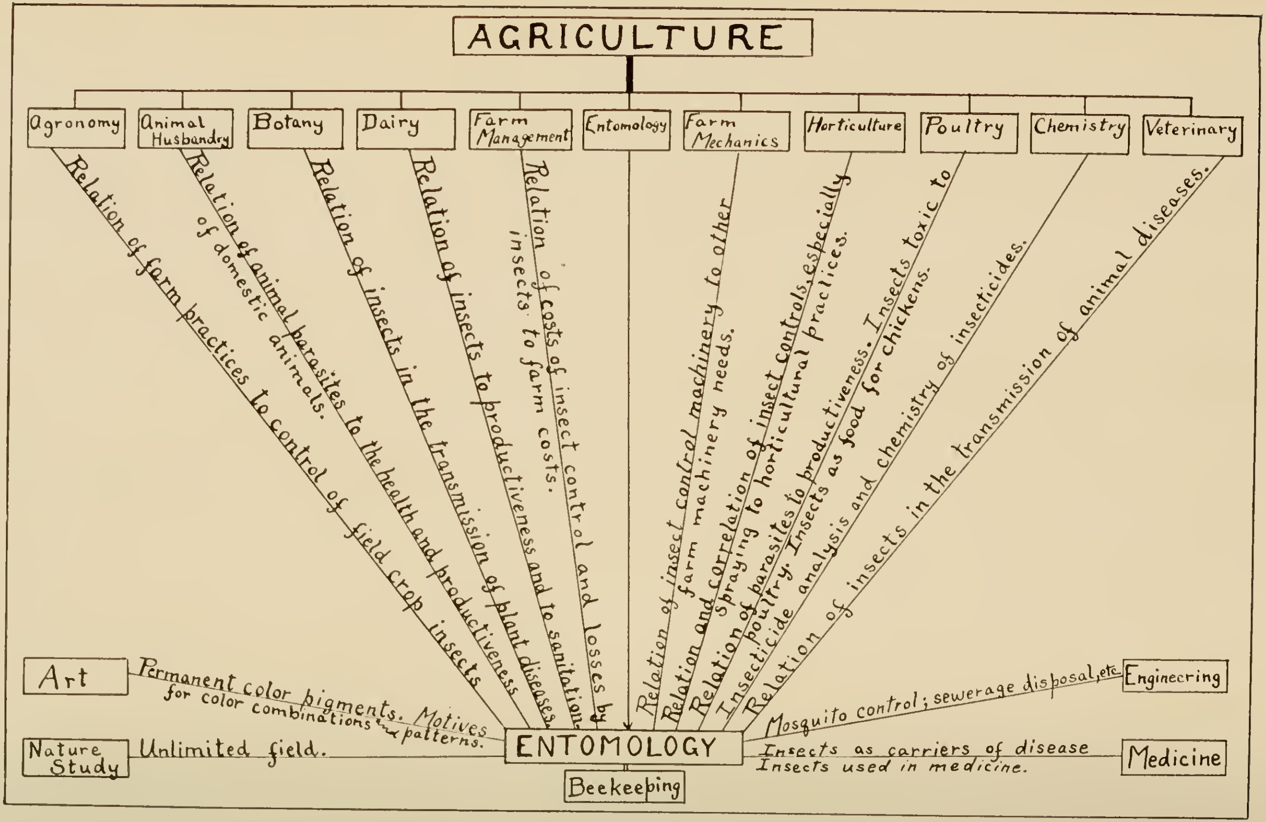

Fig. 1. The relation of entomology to the sciences, and to agricultural subjects in particular.

are essential. The application of farm practices, including as it does methods of growing and handling crops, involves the engineer in the case of drainage, the agronomist in such practices as rotation and cultivation, the crops expert in the study of resistant varieties, the animal husbandman in the problems connected with animal parasite control, the physician and veterinarian in the study of insects and disease, and the botanist in the study of insects and plant diseases. Even the lawyer becomes involved when we consider entomology in its broadest sense, for the present day inspection, insecticide and quarantine laws require his services in more ways than one. In this connection, the accompanying figure (fig. 1) will give an idea of the relation of insects to other sciences, particularly to the agricultural sciences.

Just a final word regarding the work of the entomologist. We might for convenience group it into four divisions: (1) Teaching, (2) Extension, (3) Investigation and (4) Regulatory.

1. **Teaching.** In teaching work two classes of students are involved. First, those who require it as a part of their course in agriculture, forestry, sanitary engineering and the like, and who desire such information about insects, their recognition and control as should be of most practical value to him in his future work and to lead him to acquire a foundation in the principles of entomology that will serve as a guide in solving new and unexpected entomological problems or applying the knowledge gained to his particular conditions. Second, those who wish to fit themselves for professional work in entomology.

2. **Extension work.** Under extension work we might include demonstration of control measures, newspaper and bulletin publicity, farmers' institutes and the like. Extension or demonstration work must be considered an important feature of the entomologist's routine. In the past there was some question as to whether extension was a part of the entomologist's work. I recall a story related by S. A. Forbes. A few years after taking up the work as entomologist of Illinois, Forbes noticed that although he had accumulated and published the results of many investigations and had thereby furnished in writing the methods of controlling or subduing certain insect pests, the farmers seemed to make little use of his results. He called the attention of this matter to Richard Oglesby, then governor of Illinois, and pointed out that further means should be taken to induce farmers to use better methods of control. The governor's reply was to the effect that whether or not the farmer made use of his recommendations was none of his (Forbes') business, that his responsibility ended when his work was done to the best of his ability and he had published his results in the form and manner provided by law. Then, to illustrate his point, he thanked heaven that his own responsibility ended when he had made his recommendations, in his annual and special messages, to the legislative bodies, and that he was not himself responsible for the acts of the state legislature. In his address as president of the American Association of Economic Entomologists in 1893, Doctor Forbes emphasized the fallacy of this policy in the following words: "It is not the facts of entomology we discover, but those which we persuade the farmer,

the gardener or the fruit-grower to use diligently for the protection or the preservation of his crops, which make our entomology economic. To publish valuable results without making sure of their appreciation and appropriation by our constituents, is to fail of real usefulness. To bring a result to bear on the practice of one man only when a thousand are suffering for the want of it, is to fail in 99.9 per cent of our proper undertaking. We must first do exact, exhaustive, conclusive, practical, economic work, and then we must find means to get that work utilized or it is an economic dead loss".

The correspondence of the entomologist may be considered as extension work and is not routine as might be generally supposed. The three steps in insect control are diagnosis, prescription and application. Thus every inquiry must be handled as an individual case and must be diagnosed and information furnished accordingly, much as a physician would diagnose a human ailment. The third step in insect control—application—is of course dependent on the person who must apply the remedy and too often the remedy proves ineffective because of faulty application—as poor or improper materials, or equipment, or lack of timeliness or thoroughness of application.

3. **Investigation and Research.** The investigation and research problems in economic entomology include various phases of work. First of all the investigator must have a thorough knowledge of the facts connected with the method and type of injury. A general study of the life history and habits of the insect must be made and this ordinarily must be followed by a complete and careful study of the various phases of the life of the insect and of its habits which may necessitate detailed studies, including studies in tropisms, ecological relations and the like. These may be very simple or more likely complex investigations. The life history must be studied from all angles and under the possible varying conditions, and the results of these studies used as a basis for theoretical controls. These theoretical controls must be tested first in a small way and sometimes it is necessary to test out hundreds of materials or methods before likely controls are found. The most likely methods of control as determined by the small plot tests are then tried on a large scale and these we term field tests or experiments. In all control work it is essential that the entomologist be in constant touch with the agronomist, horticulturalist, botanist and forester in order that his recommendations may not be at variance or interfere with the most approved farm practices. The discovery and formulation of methods of controlling or subduing insect pests is of course the prime function of the economic entomologist. In all experimental work, it is essential, if truthful, dependable and lasting results are to be obtained, for the investigator to exercise the highest degree of fairness and accuracy in recording and interpreting results, and to eliminate or at least make due allowance for any disturbing or unnatural influences which may enter into the problem.

4. **Regulatory.** We may include under this heading all activities having to do with the enforcement of laws pertaining to entomology, such as nursery inspection to protect the orchardist against the intro-

duction of certain serious pests, apiary inspection to protect the bee-keeper against foul-brood and other troubles, insecticide regulations to guard against inefficient insecticides, and quarantine regulations to protect the state or sections of the state from new insect pests or those not generally distributed.

Supplementary to the studies already mentioned, the entomologist must have a thorough knowledge of insect classification and be able to identify the thousands of insects which come to his attention annually. The importance of immediate and correct identification of insects is of vital importance and while the common and usual insects are readily identified those occurring periodically, those of uncommon occurrence, and those foreign to the state or nation can usually be identified only with the assistance of a reference collection.

The work of the entomologist's office has many features in common with that of the weather forecaster. We are gradually assuming the rôle of insect forecasters and I believe it will be only a comparatively short time until the entomologist will be able to forecast with reasonable certainty the likely occurrence in destructive numbers of this or that insect. This is already possible in the case of some of our common pests, such as the wheat jointworm, Hessian fly, white grub, chinch bug, periodical cicada and others. Forecasting necessitates a careful study of the past history of insect outbreaks, their causes, the relation of croppings, weather, parasites and the many other factors connected with insect life. In other words, with the forecasting of insect trouble as an important routine of the entomologist's office, we find that the entomologist must be an ecologist and have a working knowledge of the fundamental principles of the various branches of agriculture and other sciences. This phase of entomology further illustrates the intimate connection which it bears to all phases of human life.

The entomologist must ever be alert for pests foreign to the state or nation. Probably a majority of our major insect pests are of exotic origin and it is noteworthy that many of these pests are not of any great importance in their native habitat so that we cannot always depend on the status of an insect in its native home as a criterion for its acts in America.

And finally, what is the future of insect control? Certainly the kinds of insects attacking our cultivated crops are going to be more numerous in the future. Insecticides are now the major methods of direct control and they will continue as essentials to insect control but we will need to make further and more intensive investigations to find cheaper and more effective materials and methods. The cultivation of resistant varieties is likely to be an important feature of future insect control but above all the further development of insect control by farm practices and by the biological method—control by natural enemies—are certain to be among the most important factors in insect control work a hundred years hence.