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ON THE STUDY OF FOREST ENTOMOLOGY IN AMERICA.

BY

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In former addresses by presidents of this Association, many different phases of the subject of economic entomology have been discussed. A review of these twelve addresses would be interesting and valuable as a reminder of the many good things presented in each. Even a list of the titles will be suggestive of the field covered, and remind those of us who had the pleasure of hearing the addresses of their striking features and the individual characteristics and special lines of thought and work of the authors:

First. The Outlook of Applied Entomology, by C. V. Riley. Champaign, Ill. 1890.

Second. Economic Entomology, by James Fletcher. Washington, D. C. 1891.

Third. Work of the year in Economic Entomology, by S. A. Forbes (first vice-president). Rochester, N. Y. 1892.

Fourth. The Drift and Balance of our Progress for the Year, by S. A. Forbes. Madison, Wis. 1893.

Fifth. A Brief Account of the Rise and Present Condition of Applied Economic Entomology, by L. O. Howard. Brooklyn, N. Y. 1894.

Sixth. Entomological Notes and Problems, by J. B. Smith. Springfield, Mass. 1895.

Seventh. The Evolution of Economic Entomology, by C. H. Fernald. Buffalo, N. Y. 1896.

Eighth. The Present and Future of Applied Entomology in America, by F. M. Webster. Detroit, Mich. 1897.

Ninth. The Duty of Economic Entomology, by H. Osborn. Boston, Mass. 1898.

Tenth. The *Laissez-faire* Philosophy Applied to the Insect Problem, by C. L. Marlatt. Columbus, Ohio. 1899.

Eleventh. Objects of the Association of Economic Entomology, by C. P. Gillette (first vice-president). New York. 1901.

Twelfth. Life History Studies on the Codling Moth, by C. P. Gillette. Denver, Colo. 1902.

For this, the thirteenth address and fourteenth meeting, the subject of Forest Entomology in America has been chosen for at least two reasons: (1) It deals with a different phase of the science, and (2) it is a subject which will be taken up as a special feature of the work of the Division of Entomology, United States Department of Agriculture, after July 1, 1902.

The primary object will be to discuss some features of the study of forest insects in America in a way which may be of service to the student and young investigator, rather than to attempt to consider the deeper problems for those of you who are already specialists in other branches of entomology.

While forest entomology has received more attention in some European countries, especially Germany, than has any other branch of the science—and forest officials there are required to have special training in the study of insect enemies and methods of combating them—it has been comparatively neglected in America. Indeed, it has only been within recent years that a sufficient need has been recognized to justify giving it special attention. Great monumental works like those of Ratzeburg of Germany, published in 1839–1844, together with the rapid advancement at that time in systematic forest management and government control of forests throughout Europe, inspired a great interest in the subject, and led to a realization of the practical importance of a knowledge of insect enemies of trees in the successful management and protection of the forests. Therefore a knowledge of forest entomology was early recognized in Germany as one of the important features in the training of forest students and forest offi-

cials. Other important contributions followed those of Ratzeburg until there is a mass of published data which is invaluable to the foresters of Europe. But these contributions, valuable as they are to the forest interests of the older countries with long established forestry systems, relate to conditions very different from those prevailing in America. Indeed, they are valuable only to the advanced student and investigator in this country, and are not valuable or specially useful to our young students, foresters, and managers of private estate. In the aggregate there has been much original and compiled matter published in the United States relating to the insects of forest and shade trees, notably by Harris, Fitch, Walsh, Riley, LeConte, LeBaron, Saunders, Lintner, Packard, and others. Within recent years considerable additional matter has been contributed by official entomologists, but up to the present time we have nothing in the line of special instructions in the study of forest entomology that is adapted to present conditions and needs in this country.

The fifth report of the United States Entomological Commission on Forest and Shade Tree Insects is the only important attempt at a general discussion of the subject. This, as stated by the author, was "designed merely to give to the public, especially those persons interested in forestry and the planting and cultivation of shade trees, a brief summary of what is known [up to January, 1888] of the habits and appearance of such insects as are injurious to the most useful kinds of trees."

This work served a most excellent purpose by bringing together in one volume the principal records of observations of forest insects by American entomologists, and has doubtless stimulated others, as it did the present writer, to an active interest in the subject of insect enemies of trees. But it would seem that there is at present a special need of an introduction or guide to the study of forest entomology for the special use of students in forest schools and others who desire general nontechnical information on the subject.

It is, therefore, my object in this address, like the pioneer making a preliminary survey in a new country, to consider the general features of the subject and leave the details to be treated in succeeding contributions as the evolution of the forestry movement in this country indicates the need.

FORESTRY AND FOREST PROBLEMS.

Forestry, which relates to the investigation of forest problems and the management of forests with a view to utilizing their products and perpetuating their resources and beneficial influences, is becoming recognized as a branch of applied science which involves some of the greater economic problems of this country.

It is made a feature of recent messages of Presidents of the United States and governors of some of the principal States. It is the subject of exhaustive Federal and State legislation. Large sums of money are annually appropriated for the establishment and maintenance of National and State forest reserves and parks, and for special research in many branches of science which have a direct bearing upon the utilization and preservation of our forest resources.

Within recent years both public and private funds have been devoted to the establishment of forest schools. Notably to the College of Forestry at Cornell University, the Forest School at Yale, and the Forest School of the Biltmore estate. Courses in forestry have been established in many of the universities and colleges, and it is even proposed to introduce the study into the common and high schools.

There is a notably increased interest in scientific investigations of forest problems manifested by the managers of some of our great railroad systems and by other companies who are extensive manufacturers and consumers of forest products. This is demonstrated by the rapidly increasing demand for special investigations and literature relating to American forests; and it indicates a general appreciation of the value of forests in their relation to public and private interests and the need of their protection.

Investigations within recent years, by the writer, in the hardwood and coniferous forests of West Virginia, the great coniferous forests of the Northwest, the pine forests of the Black Hills reserve, and the spruce woods of Maine, convince him that the depredations by insects on the living timber alone cause injuries amounting to many millions of dollars annually. A study of the insect depredations on forest products, such as railroad and other construction materials, tan bark, and minor products, makes it plain that the actual loss in money and labor amounts to many millions of dollars more each year.

Forest entomology is a branch of economic entomology which treats of insects in their relation to forests and commercial forest products, as distinguished from those which relate to farm and garden plants, and to fruit, ornamental, and shade trees.

While the determination of successful methods of protecting the ornamental and shade trees of private grounds and parks from injurious insects will depend largely upon information contributed by forest entomologists, such trees are, as a rule, grown under different conditions and subject to treatment similar to that applied to fruit trees and cultivated plants, which is not practicable in the forest. The acquiring of information by the forest entomologist involves the determination and classification of the species of forest insects, according to their systematic relations to each other, their relations to the trees they infest, and the economic results of their work; a detailed study of the life history and habits of the more important injurious and beneficial species; a

special consideration of the influences and natural laws which contribute to favorable or unfavorable conditions for their life and work; and the conducting of experiments to determine practical methods of preventing losses from the ravages of the destructive species.

The information to be collected and disseminated is of two kinds: (1) That which is of a technical nature, as contributions to the advancement of science and for the special benefit of students and investigators; and (2) that which is capable of immediate practical application in the management of public and private forests and in lumbering operations.

In addition to a special knowledge of entomology, pure and applied, the student who desires to become a good forest entomologist should have a general knowledge of the science of forest zoology, forest botany, geology, chemistry, physical geography, and economics. It is also important that he have some experience or special training in practical methods of forest management, and knowledge of the manufacture and use of forest products. The universities and especially the forest schools and colleges will give the desired preliminary training in forestry, and works on general entomology, such as those by Harris, Packard, Comstock, Smith, Howard, Sanderson, and other American writers, supplemented by some of the principal foreign works, will fill the requirements for information about insects in general.

After this general knowledge is acquired, together with some training in methods of utilizing published data as guides to methods of study and to the discovery of new facts, the forest will be the school and nature the teacher which will finish the student's course and determine his right to a degree. Indeed, the student who will attain the greatest success in this, or other branches of entomology, will be the one with a natural or acquired ability and love for the work who will seek out the insects in their natural haunts and rely upon and cultivate originality in methods of observation and in collecting and recording data on which to base conclusions.

There is, perhaps, no branch of science which offers greater opportunities for the discovery of new facts and the contribution of valuable information than forest entomology. In this field very little is known compared with what there is yet to be learned. Especially is this true in regard to the life history, habits, and distribution of the injurious and beneficial species. Yet this knowledge is of the greatest importance in determining and applying methods of preventing losses.

There are, indeed, hundreds of subjects and special problems in forest entomology worthy of a lifetime study by as many specialists. There are many families, groups, and genera of insects represented by the principal enemies and friends of the forest which are sadly in need of detailed study by specialists for the accurate identification of the species and a complete revision of the literature. The insects of

the pines and spruces, the cedars, oaks, and hickories, and many others of our principal forest trees, offer excellent opportunities for original investigation and the contribution of information of great importance.

METHODS OF WORK AND STUDY.

In addition to general methods of collecting, preserving, and mounting insects, as given in text-books on entomology, some suggestions may be offered for studying forest insects and for the investigation of their work.

First of all, the student should keep in mind that there are many collectors of insects and many students in general entomology, as well as numerous specialists who are collecting and studying insects of all orders found in the forest and field. Thus he should avoid general collecting, and devote his time to the accumulation of specimens and observation on life histories and habits of insects which are associated with injuries to forest trees or forest products.

In addition to a general study of insects which have some economic relations to forests, he should select, at as early a date as possible, some special subject for detailed study. There is no lack of important subjects, as has already been suggested, but in making the selection the prevailing conditions, opportunities, and facilities in the immediate vicinity or sections in which the studies are to be conducted should be considered. If it is in a pine region, insects affecting pines will offer the most desirable opportunities for study; if in a hardwood region, those affecting the oaks, hickories, chestnut, and the like will offer the best opportunities. If there is some prevailing injury to a given kind or class of forest trees, this will at once suggest itself as the most important to take up. It matters not whether it is the study of the insect fauna of a species or genus of forest trees, the causes of a special class of injuries, or the study of a single family, genus, or species of insect. There is enough in each case to keep the student occupied in original researches for many years, and to furnish sufficient material for contributions to the literature of the subject. Indeed, every student who takes up forest entomology as a life work should start out with the object of acquiring and disseminating as much knowledge as possible on some special feature of the science. To thus become a specialist of this kind does not necessarily imply that he will have a narrow comprehension of the entire subject. Even if one were to try to find out all that is to be known about a single enemy of a forest tree, and every possible method of preventing losses from its work, his work would involve a general knowledge not only of forest entomology in its broadest sense, but of all related sciences and subjects. In fact, as a great thinker has said, in order to know all about any one thing it is necessary to know all about everything. While this may not be literally true, it is becoming recognized that there is almost an unlimited interrelation of all sciences and all subjects.

COLLECTING SPECIMENS AND RECORDING OPERATIONS.

The equipment for collecting specimens need not be expensive or elaborate. The necessaries are: A hatchet or light ax, carried in a scabbard, which may be fastened to a stout belt; a hunting coat, or an ordinary sack coat, with many pockets; a supply of collecting vials of various sizes, fitted with the best cork stoppers; a small bottle of alcohol; a medium and a small cyanide bottle; tweezers; camel's hair brushes; a stout knife with small and large blades; a small saw; a net and umbrella; and last, but not least important, a notebook and pencil. With this equipment, or such part of it as is required for the special kinds of specimens desired, a good observer can go out in the woods any day in the year and find plenty of material.

The best places to collect species infesting wood and bark is along the edge of the woods, or where trees have been girdled or felled a few months previous. Here one will usually find in the bark of the roots, stumps, main stems, tops, branches, and twigs different stages of many species of bark-beetles and bark-inhabiting larvæ, together with their natural enemies and associates; and the wood will yield many more.

Lumbering regions and sawmill yards are especially prolific in specimens at all times, as are also broken branches, individual trees, and groups injured or killed by insects, felled by storm, or otherwise rendered attractive to insects. During the spring, summer, and fall the foliage will yield specimens almost unlimited in number and variety. But one should remember, as has already been indicated, that it is not the number and variety, but those of most importance, that are to be sought out, noted, collected, and studied. It is often better to spend a day in the diligent search for all that can be found in or on a single tree, or in observing and recording in the notebook all that can be found out about a single species, than merely to collect hundreds of specimens or many species without careful records.

Indeed, the proper recording of what one sees at the time the observations are made is of the greatest importance, and is the one thing the student should practice more, perhaps, than anything else.

RECORDING OBSERVATIONS.

While nearly every entomologist has adopted some system of taking and keeping notes on observations in the field or laboratory which is specially adapted to his own line or method of study, and shows marked peculiarities, there are certain general principles and rules which should be laid down for the consideration and guidance of the student and amateur investigator.

In collecting specimens and in field observations the notes taken should include the following: The exact locality (the nearest post-office, hill, mountain, or farm); when possible, the elevation and the exposure; the date; the host plant; point of attack; what stages

occurred, etc. If it is associated with any special injury or trouble affecting the plant or object from which it obtains its food, the fact should be noted. As many details as possible should be briefly or fully noted. Every separate note referring to collected material should be numbered. In regard to the use of numbers, it should be specially remembered that the numbered specimens serve as an index to the notes relating to them. Therefore the same numbers should never be used a second time. The student should start out with the idea of using consecutive numbers as long as he collects insects. At the same time economy should be practiced in the use of numbers, and this can be accomplished in many ways; as, for instance, No. 1 may be made to refer to more than 100 different entries relating to insects collected on the same date and from the same tree. It may be used 26 times with a letter of the alphabet preceding it (as a1, b1, etc.), 26 times more with letters following it (as 1a), 26 times more with a letter over it, and indefinitely with decimals or fractions. The object in view is to adapt the numbers to all requirements without the necessity of repeating or having them attain inconvenient proportions.

If the object in view is simply to get the specimens, then the locality and date, with the collector's name, are all that is necessary to accompany the specimens in the bottle or on the pin. If the student has ambitions, however, to accumulate material and data which will be of the greatest value, he will give special attention to the accumulation of material which represents more than localities and dates. Our museums and private collections are already oversupplied with this kind of material, which is well enough as far as it goes; but the student who would be satisfied to go no further than this had better not enter the field of forest entomology. His place would be in the museum with dead specimens—a place, by the way, where a vast amount of good and indispensable work is done in systematic study and identification of specimens; but this is in the line of pure science, while the forest entomologist's ambition should be to contribute to the advancement of both pure and applied science. He can do this best by recording as many facts as possible about the specimens he collects and observes.

After the student has progressed far enough to be able to accurately identify the principal species as they are observed in the field, very many observations may be recorded without collecting specimens or the use of numbered notes. But this should not be attempted until after years of practical work, and even then it can not be reliable except with such species as are perfectly well known. Observations and records based on field identifications by some of our best entomologists have led to much confusion in literature about some of our common insects. This has been abundantly demonstrated by the writer in a recent study of the types of Scolytidæ, described by one of

the best American authorities on the Coleoptera of North America. There are a number of examples where a common enemy of forest trees has been identified from descriptions or from observation in the field as a certain species, and after a great deal has been published under the erroneous names it has been found upon comparison with the types that it was quite a different thing, with different habits from the species to which the name properly belonged; and in some cases what was supposed to represent a well-known species was even found to be undescribed. It will, therefore, be readily seen how important it is for the species we write about to be accurately identified, and how necessary to have a numbered specimen to refer to for future corrections or to send to a specialist for authentic identification.

It is always of the greatest importance to observe the character of the work of the insects when found in their natural feeding or breeding places; and, whenever possible, specimens of the work should be secured for the collection, especially the work of wood and bark boring species and that showing special or characteristic injuries to the foliage, etc.; and each should, as with the insect specimens, be accompanied by the note number.

It is also important for the beginner to collect large numbers of specimens both of the insect and its work whenever the opportunity offers. For, even if there should be more than he needs for his own collection, they may be specially valuable for exchange with other collectors for desirable material from other localities and countries. One of the commonest mistakes made by most young collectors, and, for that matter, many older ones, is the failure to avail themselves of the very first opportunity to collect an abundance of material relating to any desirable species. It must be remembered that because an insect is common at one time or place it does not always follow that it will continue to be so or that it is common in other places. Indeed, the reverse is the rule. A period of great abundance is usually followed by a period of great rarity, or, as has sometimes happened, almost complete extinction.

The collector should be constantly on the lookout for the natural enemies of the principal injurious species. One class of the enemies of insects consists of parasitic Hymenoptera, Diptera, etc., found in the adult larval or pupal stage, associated with their host, the larvæ as external or internal feeders on the larvæ, pupæ, or adults of the injurious species, and the adult parasites ovipositing on or in the victims, or in the bark or other infested parts of the plant. The other class of insect enemies of insects are predatory species of Coleoptera, Hemiptera, Hymenoptera, and other kinds of insects which attack and kill their victims, and either devour them or suck out the liquid parts of their bodies. There are also insect diseases which may be indicated by a white powdery substance on the bodies of the dead

insects, and, whenever numbers of examples are found to be dead or dying, specimens should be collected and submitted without delay to some specialist on this class of diseases.

METHODS OF COLLECTING AND REARING LIVING MATERIAL.

It is always desirable to collect living material to rear or breed for the purpose of securing data on life histories and habits. This will consist of eggs, larvæ, and pupæ of foliage-infesting insects to be reared in breeding cages; also bark, wood, branches, and twigs infested with immature stages, to be reared to adults in breeding jars, boxes, or cages.

Specimens from the foliage should be collected in small tin boxes, together with a small amount of their natural food. Some of the smaller things may be reared in the boxes in which they are first collected, if supplied from time to time with fresh food material, while others must be transferred to breeding cages or larger tin boxes. Living specimens in wood or bark are easily collected in sections cut from the infested parts of the plant, and carried in the larger pockets of the hunting coat; or, if a long distance from the laboratory, they may be packed in bundles or boxes and shipped by the most convenient method available.

For breeding specimens from this kind of material, the writer has secured excellent results by the use of different-sized fruit jars with clamp covers. The screw-topped jars are also very convenient for this purpose. For very large sections, or a large amount of material of one kind, tight barrels or large wood or galvanized-iron boxes may be used to advantage.

For carrying on the more elaborate work of rearing from wood and bark, a specially constructed insectary is necessary. Wood and bark infesting larvæ and pupæ, and parasitic larvæ in cocoons, may be successfully reared to adults in bottles or vials which are just large enough to accommodate single specimens. These small vials with cork or cotton stoppers are indeed specially convenient for the rearing of parasitic larvæ and pupæ taken from the mines or pupa cases of the wood or bark-inhabiting host.

PRESERVING, MOUNTING, AND LABELING SPECIMENS.

The specimens that are killed in 25 per cent alcohol should be removed from the bottles in a day or two after they are collected, then cleaned thoroughly and replaced in clear 80 or 90 per cent alcohol. The specimens killed in the cyanide bottle should be gone over, separated, and either mounted or stored where they will be free from museum pests.

The specimens of work of insects should have the surplus parts removed, and should be labeled and stored where they will be readily

accessible for future reference. Broad shallow drawers or trays are convenient for the smaller wood and bark specimens, while wood or heavy paper boxes serve for larger ones. Common florists' paper boxes, which are shipped flat ready to be made up, are excellent for storing the classified material.

Every individual specimen should have the number of the note referring to it, or the series to which it belongs, and also something to designate the particular set of notes or accessions catalogue to which the number refers, as "500, Hopk., W. Va.," which means entry No. 500 in the accessions catalogue of the entomological department of the West Virginia Agricultural Experiment Station, Morgantown, W. Va., A. D. Hopkins, collector. As long as the specimens remain in the collection with the catalogue these accession numbers are all that is necessary for the duplicate material, since they serve at once as index to the readily accessible notes. If, however, any of the specimens are transferred to other collections they should always bear labels showing date, host, and such other facts as are of primary importance to preserve their identity, or if a large number of examples of different species are sent a list of species and accessions catalogue numbers with extracts from original notes should accompany them, together with the address of the individual or institution having permanent charge of the accessions catalogue.

The specimens of the work of insects may have the number and other data written on them, or on paper labels and pasted on or otherwise attached. If the specimens are fastened on cardboard or to the bottom of the case, labels may be printed and pasted beneath them.

WHAT TO STUDY.

After the student has acquired some knowledge of how to study, collect, and make proper records of observations, and how to label and preserve specimens, it is important for him to consider well what there is of importance to study and investigate, and how to get results of practical value. Forest entomology embraces only such insects as are in some way related to human interest in forests and forest products. Therefore, the student must confine his studies to the insect fauna of the forest growth which is of some economic importance, with the view to determining which kinds are injurious, which are beneficial, and which are neutral in their relation to the life history of the plant and the future usefulness of its products.

Commencing with the matured seed or fruit of trees, such as the oaks, hickories, walnut, and others, we find that not only the nut or seed, but its envelope (hull or pod), is the home of many kinds of insects. On the tree, fallen, stored for use, or planted in the ground, they support some different kinds of insect enemies or guests, as they do, also, from the time the seed bursts open and the roots and stem

begin to form through all stages of the seedling, the sapling, the young, matured, old, dying, dead, and decaying tree. Not only does the tree, during each stage in its life history, death, and decay, support some kind or kinds of insects peculiar to each, but every part—the rootlets, the larger branching roots, the main roots, the lower stem, the upper stem, the large and small branches, the twigs, the buds, the young leaves, the flower buds, the different parts of the flower, and the embryo fruit—will have its special guests. Some kinds inhabit the outer bark; others, the intermediate or inner bark, the cambium, the outer or inner sapwood, the heartwood, or the pith.

Not only during its life, but from the time it dies until it is entirely decayed and converted into humus, a tree supports many and varied forms of insect life. Some are its enemies, some its friends; others, neither enemies nor friends, but guests and scavengers. Among its enemies some have special designs upon its life in order that its dying may furnish favorable conditions for the rapid increase of the insect progeny, and consequent increased power in numbers to attack and kill other trees. Some are enemies only to the extent of causing injuries to the roots, bark, wood, branches, and foliage which may be detrimental to its perfect development or its future usefulness to man, but have little or no immediate effect upon its vitality. Others are enemies only so far as they obtain their food from some living part, yet do no permanent injury, such as certain kinds of leaf-eating, sap-sucking, and gall-making insects, which are never or rarely common enough for special harm. There are many other kinds which obtain their food directly from the dead parts of the living tree, such as the outer bark, dead twigs and branches, dead wood, etc., which can scarcely be considered as enemies of the living tree. Among the friends of the living tree are the insects which feed upon the injurious kinds, either as internal or external parasites, or those which attack and devour their prey. Among the guests of the injurious and beneficial inhabitants of the tree there are many kinds which live in the burrows and feed upon the sap, borings, excrements, dead insects, etc., while there are many other kinds which utilize some part of the tree or the burrows of other insects as hiding or hibernating places.

THE INSECT FAUNA OF FOREST PRODUCTS.

The natural products, such as nuts, medicinal roots, bark, and leaves, tan bark, etc., each, under certain conditions of storage and age, furnishes feeding and breeding places for many kinds of injurious, beneficial, and neutral species. The manufactured or commercial wooden products of all kinds, the crude round or square timbers, lumber, staves, hoop poles, etc., are, under certain conditions, subject to attack or serious injury from various kinds of insects while in the woods or

when stored in yards and factories. The seasoned and finished products, especially those from sapwood, may be infested and destroyed by a number of species of so-called powder-post beetles. Construction timbers and lumber, either before being utilized or while in the structure, are subject to injuries by many injurious and other species. The old lumber and timbers of barns and outbuildings, old log and frame dwelling houses, are also infested and injured by forms which are peculiar to such material.

THE ECONOMIC RELATION OF INSECTS TO FORESTS.

The preceding references to the insect fauna of forest trees and their products are suggestive of the vast numbers of kinds, groups, and societies of insects and the kind and character of injuries to be studied. This leads us to a consideration of the economic relation of insects to American forests under the varying conditions which prevail before and after the country is settled and its resources developed.

The relation of injurious insects to the primitive forests.—The relation of insect enemies of a forest before its resources are available to civilized man is of little or no economic importance. They are simply factors in the general struggle for existence between insects and trees, and between the individuals of the forest community in which the destruction of an individual tree by insects is a benefit to other insects and other trees. If a matured or old tree is killed, it gives more room for the development of the younger and more vigorous ones. The injured, declining, and old individuals furnish breeding places for successive communities of insects, which contribute to their death and rapid decay. Thus the young tree growth is favored by light and plant food, and soon fills up the vacancy. Invasions of destructive insects may cause the death of one kind of tree growth over vast areas. This favors the enormous multiplication of the insect fauna until the destructive species perishes for lack of food supply, or from the multiplication of its natural enemies. This proves to be a calamity to the other insects which have depended upon the destructive species to furnish, in the dying and dead trees, the required conditions for their existence. The dying and dead trees and the fallen and decayed branches, bark, and roots contribute to a more vigorous reproduction, so that the forest found by the pioneer settler has lost nothing from its insect enemies.

The relation of the insect enemies of trees to the pioneer settler in a forested country may be more beneficial than otherwise, so far as his immediate needs are concerned. The forest must be cleared from the land that is desirable for agricultural purposes, and in this process the depredating insects may be decidedly beneficial. They contribute to the death and rapid decay of the girdled trees in the clearings and hackings. Invasions which cause the death of the large timber over

great areas may be utilized to the especial advantage of the agriculturist, and contribute to the prosperity of the community of settlers. The dead trees, with the fallen tops, furnish the most favorable conditions for the process of clearing by fire. It saves the expense of girdling. Often the flint and tinder or the torch was all that was necessary to start a conflagration which effectually cleared the land of dead and felled timber, and killed the remaining living trees and young growth.

The relation of insect enemies to the forest of a settled country.—The great destruction and waste of the best of the forest resources necessary to the progress of civilization finally reaches a stage at which the forest is more valuable for its commercial products of timber, its protection of springs and head-water streams, than is the land for agricultural products. Thus as time progresses the insects become more and more injurious in their relation to the public interests. The destruction of matured timber by insects comes to be recognized as a serious loss. Their burrows in the wood of living and dead standing timber and that felled for saw logs and other purposes are recognized as serious defects which reduce the profits of the manufacturer and increase the prices of the clear product to the consumer. The injuries to the young growth which result in the development of a deformed, worthless tree become an element of future financial loss. The areas of dead timber killed by insects become a menace to the forest, furnishing as they do favorable conditions for the outbreak of destructive forest fires and the development and spread of wood-boring insects.

While the more destructive kinds of bark-boring insects may aid in the death of girdled trees, such trees at the same time furnish favorable conditions for the rapid multiplication of the insects and thus contribute to destructive depredations on the valuable living timber in the adjacent forests.

As the merchantable timber and the manufactures of wood become scarcer and the price to the consumer increases, the depredations which a few years before would have remained unnoticed attract more and more attention, and the need of methods of preventing losses from this source is fully realized. Then requests are made for information relating to the kinds of insects that cause the troubles and the details in their habits which is necessary in order to successfully combat them.

Their relation to the public and private forests and farmers' wood lots.—The relation of injurious insects to forests which are under systematic management present quite a different problem from those relating to more primitive conditions. In dealing with the latter there is little opportunity for the practical application of a knowledge of forest entomology, but the former present economic problems worthy of special study and investigation. All of the injurious species may be considered in this relation as enemies, not only to the forests but

to public interests. The introduction of forestry methods offers opportunities for the adoption of methods of preventing much of the losses which under previous conditions could not be avoided. It also offers opportunities for extended research and experiments for the determination of the more important facts relating to the habits and life histories of the insects and their depredations, which will lead to the discovery of improved methods of control.

THE KINDS AND CHARACTER OF THE WORK OF INSECT ENEMIES OF THE FOREST.

The fruits of forest trees are injured by the adults and larvæ of species which feed upon the pulp, pod, or other covering, and thus destroy the seed or prevent its normal development. The seeds are injured or destroyed by beetles and their larvæ, by the larvæ of moths, and by gall-making insects. Nuts of all kinds and the hard fruit of many trees are infested by larvæ from eggs deposited in the growing fruit by small beetles. The entrance of the young larva through the young, tender hull or outer shell heals over so that the ripe nut shows no trace of it. The larva feeds on and destroys the germ and kernel and, when fully grown, bores its way out and enters the ground, where it goes through the transformations and emerges as an adult next year in time to deposit its eggs in the young nuts. Thus the seeds of some trees may be so completely destroyed that few remain for reproduction. This may cause considerable expense and loss to the forester, both in adding to the expense of collecting a sufficient quantity of sound seeds and in causing an uneven stand in the nursery on account of the damage to the stored and planted seeds. This class of injuries also causes a serious loss of the commercial product of chestnuts, hazelnuts, hickory nuts, etc.

The seedling in the forest or in the nursery row is attacked and injured by many kinds of insects. The roots are eaten by the larvæ of beetles and the sap sucked out or poisoned by root-lice. The stem is attacked by wood and bark-boring beetles and grubs. The foliage is devoured by caterpillars, larvæ of sawflies, and grasshoppers, or injured by plant-lice, scale insects, leaf-hoppers, and leaf-bugs. The twigs are injured by twig girdlers, twig miners, scale insects, and plant-lice. As a result, the seedling may either be killed or become stunted or deformed.

The young tree is in a like manner attacked and injured or killed by one or more enemies of the roots, stem, or top. The principal injuries, however, which are characteristic of the growing tree, are those made in the roots and base of the stem by the great root borer, and in the wood of the main stem by the carpenter worms and other borers, which are capable of working in the wood of living healthy trees. While this class of enemies may have little or no direct effect upon the vitality of the trees infested by them, they cause a great loss

of commercial products. Their burrows cause defects in the wood, and are the means of starting decay, which renders the heartwood worthless for commercial purposes. The living bark may be attacked by bark-boring grubs in sufficient numbers to seriously affect its vitality, so that it will soon succumb to the attacks of other insects or diseases.

The mature tree suffers most from the many wood-boring beetles and grubs. The destruction of some of the larger roots by the great root borer causes dead branches and dead tops. The borings of the carpenter worm and other borers in the main trunk, top, and larger branches result in rapid decay, hollow trunk, and generally worthless condition, while its weakened vitality makes the tree an easy prey to destructive bark-boring enemies. The trees blown down by storm or felled by the ax are attacked by a vast number of species of insects. Some live in the bark, where they do little or no harm to the commercial product, but certain kinds may thus multiply rapidly and attack the standing timber. The wood, however, may be seriously injured by many species of wood-boring beetles and grubs which breed only in the wood of dead and felled trees.

Old dead, standing, and felled trees and old logs and stumps are infested by many insects which not only contribute to the rapid destruction of the wood, which otherwise might have some commercial value, but certain kinds breed in such material and emerge to attack the wood of recently felled trees and injured places in the standing living ones. They also attack square timbers in bridges, trestles, railroad bed, etc.

SOME OF THE PRINCIPAL INSECT DEPREDATIONS IN THE FORESTS OF THE UNITED STATES.

THE PINES.

Between 400 and 500 species of insects are known to inhabit the living, dying, and dead pines of the United States. The pine forests of the East, Northeast, and Southeast have suffered and are now suffering greatly from the ravages of destructive bark-beetles. A few years ago (1890–1892) a trouble spread over an area of 75,000 square miles in the Middle Appalachian region which resulted in the death of millions of pine trees. This included all of the indigenous and some of the introduced species in the forests, private grounds, and parks. Upon careful investigation, this trouble was found to be caused primarily by the ravages of a single species of bark-beetle (*Dendroctonus frontalis* Zimm. var. *destructor* Hopk.). Previous to 1890 this was a rare insect in collections, and nothing was known of its habits. It disappeared and the trouble ceased in 1893. This insect is liable to appear again in destructive numbers. It is therefore of the greatest importance that special efforts be made to determine the sections in the Eastern and Southern pine forests where it may yet survive, so

that measures may be taken, by introducing or encouraging its natural enemies or by girdled trap trees, to prevent its multiplication and future destructive invasions.

Recent investigations in California, Oregon, Washington, and Idaho, by the writer, under the auspices of the Division of Entomology, United States Department of Agriculture,[a] revealed the fact that the western yellow pine, Jeffery pine, sugar pine, mountain or silver pine, shore pine, and lodgepole pine has each its peculiar insect enemies, some of which are very destructive. Many of the finest examples of yellow pine were found to be dead or dying from the ravages of the western pine destroyer (*Dendroctonus brevicomis* Lec.) from northern California to northern and western Idaho. The mountain pine in northern Idaho and western Montana suffered severely from the ravages of the mountain pine destroyer (*Dendroctonus monticola* Hopk. MSS.). The yellow pine has also suffered greatly in Idaho and eastern Washington from the larvæ of a white butterfly (*Neophasia menapia* Feld.), which defoliates the trees over large areas.

Recent (September, 1901) investigations in the Black Hills forest reservation revealed the fact that a vast amount of the best timber on many thousands of acres has died within the past six or seven years and is yet dying from the ravages of the pine-destroying beetle of the Black Hills (*Dendroctonus ponderosæ* Hopk. MSS.).

It is also reported that the pine is dying in other sections of the Rocky Mountain region, from Idaho to Arizona, evidently because of the ravages of bark beetles.

It is evident from observations made in the Black Hills reservation and in the forests of Idaho, Washington, and Oregon that the death of the pine timber over many extensive areas, supposed to have resulted from fires, was primarily due to the work of tree-destroying insects. Even the meager knowledge we have been able to acquire during hurried investigations in the forest and from observations along the routes of travel through the Rocky Mountain region, the Pacific slope, and the Northwest makes it very plain that the destruction of pine timber, due primarily to the ravages of insects, has been progressing during the past half century at a rate far beyond that conceived by the casual observer or even by those who are making a study of the forests and forest conditions of those regions. Indeed, the extensive ravages of insects on the pines of the United States furnish a problem whose great importance and magnitude would justify the expenditure of large sums of money for detailed investigation by specially trained forest entomologists.

THE SPRUCES.

The spruces of this country are also inhabited by many hundreds of species of insects.

[a] Bul. No. 21 (n. s.), Division of Entomology, U. S. Department of Agriculture.

The Red Spruce of the middle and northern Appalachians, from West Virginia to northern New York and on through northern New England to Canada and New Brunswick, has, from time to time during the past century, suffered severely from troubles, some of which are known, and others believed to be, caused by bark-beetles.[a]

A large amount of spruce was killed in West Virginia about 1885, evidently by a bark-beetle, but the trouble was not investigated until 1890, so the exact species deserving the blame could not be determined.

In 1892 the destructive pine bark-beetle spread in West Virginia from the pine into the spruce, and caused the death of a large amount of the best timber.

The great destruction of spruce, which has attracted so much attention from New York to New Brunswick, was found, upon special investigation, to be largely if not entirely due to the primary attack of the spruce-destroying beetle (*Dendroctonus piceaperda* Hopk. MSS.).[b]

The Sitka Spruce of the Northwest has numerous enemies, among which the Sitka spruce Dendroctonus (*Dendroctonus obesus* Mann.) is the principal depredator in the bark of living and declining trees, while the spruce-destroying spanworm (*Philedia punctomacularia* Hulst.?) may be considered as the greatest insect destroyer of forests of this tree and the Western Hemlock.[c] Scarcely anything is known about the life history and habits of this insect. Therefore it presents a problem of special importance for investigation.

The Engelmann Spruce has a number of insect enemies, one or two of which are capable of causing wholesale destruction.

Vast quantities of dead spruce occur in different sections of the Rocky Mountain region which, it would seem, bear no trace of having been killed by fire, and the cause will probably be found to be the attacks of some destructive bark-beetle or defoliating insect.

THE HEMLOCKS.

The Eastern Hemlock has a serious enemy in the hemlock destroyer (*Melanophila fulvoguttata*), which has caused the death of a large amount of hemlock timber throughout the Appalachian and Northeastern regions.

The Western Hemlock has at least three destructive enemies of the living trees: (1) The Western hemlock bark-borer (*Melanophila drummondi*), which is closely allied to the Eastern species, and like it extends its burrows beneath the bark and either kills the trees or causes serious gum-spot defects in the wood; (2) the Douglas spruce

[a] Buls. 17 and 56, W. Va. Agr. Expt. Station, and Bul. 28 (n. s.), Div. Entom. U. S. Dept. Agr.

[b] Bul. 28 (n. s.), Div. Ent., U. S. Dept. Agr.

[c] Bul. 21 (n. s.), Div. Ent., U. S. Dept. Agr., 1899, p. 18.

bark-borer (*Asemum nitidum*), which has similar habits to those of the hemlock bark-borer; and (3) the Sitka spruce spanworm, which defoliates and kills the trees over large areas.

THE CEDARS.

The California Redwood has a special enemy in the sequoia bark-beetle (*Phlœosinus sequoiæ* Hopk. MSS.)

The Giant Arborvitæ has an enemy in *Callidium janthinum*, and the Eastern Arborvitae one in *Hylotrupes ligneus*, which infest the living trees and either kill them or cause serious defects in the wood. The other true cedars, the Monterey Cypress, and some of the Western and Eastern junipers, have a number of bark- and wood-boring enemies, which are more or less destructive.

THE FIRS.

The Western, grand, noble white, and Shasta firs, and the Eastern balsam firs are attacked by several destructive bark-beetle enemies, which either kill the trees or cause serious gum-spot defects or decayed places in the wood.

THE OAKS.

The insect fauna of the oaks is very large, probably exceeding in number of species that of the pines. Those noted for their especially destructive attacks on living trees are the carpenter worms (*Prionoxystus* spp.), which bore into the bark and wood and not only cause serious worm-hole defects, but by successive attacks cause the death of part or all of the tree. Their burrows give entrance to wood-decaying fungi which soon render the heartwood worthless for commercial purposes. The giant root-borer (*Prionus laticollis*) is another enemy of Eastern oaks in general, which is enormously destructive to large and small trees in forest, park, and lawn; but it would seem that its work is rarely recognized, and that the magnitude of the damage is not generally understood. The large, white, elongate grubs bore in the roots and bases of the trees, causing one or more of the larger roots to die. These holes and the burrows made by the carpenter worms give entrance to other wood-boring insects and wood-destroying fungi, which rapidly extend and complete the destruction of the injured parts. This decay often extends into the base of the trunk, destroying the heartwood and thus causing the tree to be hollow and worthless. The decayed wood of the roots and base of the tree also furnishes fuel for forest fires, so that the trouble started by the giant borer, and extended by other insects and fungi, is made conspicuous by a great blackened wound, which is more often than otherwise supposed to be due to fire alone. Trees are often killed outright by this root destroyer, but the work is usually so obscure that the trouble is often blamed to

other bark and wood-boring insects, which attack the tree as soon as it manifests weakened vitality.

The two-lined chestnut borer (*Agrilus bilineatus*) is another enemy of medium to large white oak and other oak and chestnut trees, which has caused the death of a large amount of this kind of timber throughout the Appalachian region.

The oak timber worm (*Eupsalis minuta*) is one of the most destructive enemies of the wood of living, dying, dead, standing, and felled trees. It causes what is known as pin-hole defects. The loss of the more valuable timber of the largest and best trees caused by this insect is enormous; indeed it is far beyond the conception of persons who have not given special attention to the subject. The ravages of this insect do not end with living and dead trees, but it continues its work in lumber and square timber from infested logs, and will even attack freshly sawed and closely piled oak lumber. This insect alone furnishes one of the big problems for detailed investigation.

The Columbian timber beetle (*Corthylus columbianus* Hopk.) causes one of the commonest defects in white oak lumber and square timber. It attacks and breeds in the sapwood of living trees, and the healed-over wounds cause pin-hole and stained-streak defects.

A serious trouble has for many years affected the oaks of the northern United States from New York to Minnesota, and has caused the death of a vast amount of timber in lawns, parks, and the forest. This has not been specially investigated, and therefore little or nothing is known regarding the primary cause.

THE CHESTNUT.

The living chestnut trees throughout the Appalachian region, and apparently wherever this tree grows, have a most destructive enemy in the chestnut timber worm (*Lymexylon sericeum*). This wood-boring worm or grub hatches from eggs deposited in the slightest wound in the bark and surface of the wood, and burrows deep into the heart-wood, causing the wood of nearly every old tree to be perforated with pin-hole defects. It attacks and breeds in dying, dead, and felled trees and stumps, and will continue to work for a time in square timber, telegraph poles, and heavy timber cut from infested trees. It also infests red oak, and often renders worthless parts of the trees which otherwise would make the highest grade timber. The enormous damage to the forest resources of the United States caused by this insect makes it one of primary importance to take up for detailed study and for exhaustive experiments with different methods of reducing the numbers of the pest and preventing losses from its ravages. The giant root-borer and the two-lined chestnut borer also attack chestnut, and in some sections do great harm.

THE HICKORIES.

The hickories of lawns, parks, and forest have suffered from time to time within the past half century from the destructive ravages of the hickory bark-beetle (*Scolytus 4-spinosus*) from Missouri to northern New York and West Virginia. Recent investigations and extensive experiments with felled and girdled trees indicate that this pest can be controlled so that under a system of improved forestry management little or no loss should result from its attack.

The poplar, tulip, beech, birch, and, in fact, all of the principal forest trees have their special insect enemies, which attack the living trees and are more or less destructive to their lives or to the commercial value of their timber products.

DEPREDATIONS IN THE WOOD OF DYING, DEAD, AND FELLED TREES, TIMBER PRODUCTS, CONSTRUCTION TIMBER, AND STORED PRODUCTS.

In addition to the primarily destructive enemies of living forest trees, there is a host of enemies of the wood of the dying and dead standing and felled trees of all species, which cause serious defects and rapid deterioration. Many of these injuries to the wood present problems of great economic importance and most promising lines of investigation in the possibilities of discovering simple methods of preventing losses.

Construction timbers.—There are a number of wood-boring insects which attack and breed in heavy construction timbers, especially those used for railroad ties and in culverts, trestles, and bridges. These are not only weakened by the borings of the insects, but entrance is given to wood-decaying fungi, which work so rapidly that, before it is realized, certain parts may be rendered exceedingly dangerous. Therefore, the relation of the combined effects of insects and fungi to accidents from the collapse of buildings and railroad structures is a subject of special interest and importance for detailed study.

Stored forest products.—Insect depredations on stored forest products, such as tan bark, hickory handles, buggy spokes, and hoop poles, is another problem coming within the range of forest entomology which demands special attention. Recent investigations of insect enemies of stored tan bark have revealed the fact that both oak and hemlock bark are subject to attack by at least five species of insects, which convert into fine powder the inner or flesh part of the bark that has been stored over two or three years. As much as $70,000 worth of hemlock bark was found to be infested at a single tannery in West Virginia, and personal investigations at other tanneries in the State, together with information from other States, indicate that this is a widespread trouble in the East and North and evidently extends into Canada.

The destruction of stored hickory, oak, maple, and other hardwood lumber, and the various products manufactured from hard woods, due to the ravages of powder-post beetles (*Lyctus* spp.), is a widespread trouble in this and other countries, and has caused the loss of a vast amount of valuable material. Yet comparatively little has been done in this country toward a detailed study of the problem and the elaborate experiments necessary to determine methods of preventing attack.

THE INTERRELATIONS OF INSECTS, FUNGI, AND FIRES IN THE DESTRUCTION OF FORESTS.

This is another problem that recent investigations have demonstrated is one of very great importance. Heretofore it has been almost entirely overlooked, and much of the destruction which has been going on in all of the great forest areas of the country that is primarily due to insect attack, and secondarily to fungi, has been attributed to forest fires, which really occupied third place among the destructive factors.

The examples of destructive insect ravages mentioned here are only a few of a long list that could be given. They should be sufficient, however, to indicate the number and the magnitude of the problems in forest entomology, which, on account of their special economic importance, should be thoroughly investigated.

The need of exhaustive study of these problems is all the more apparent when it is realized that comparatively nothing is known of the more important facts relating to the life history and habits of some of the principal depredators, the conditions that contribute to sudden and destructive invasions, or those that bring about an equally sudden ending of a serious trouble. Without this knowledge little or nothing can be done toward the recommendation of effectual methods of preventing losses. Enough has been determined from a detailed study of some of these problems to indicate quite clearly that a better knowledge of some of the fundamental facts will lead to the adoption of simple, inexpensive methods by which the loss of a vast amount of timber and timber products may be easily prevented.

REMEDIES AND OTHER METHODS OF PREVENTING LOSSES.

The problem of controlling insect enemies of forests is quite a different one from that relating to the control of farm, garden, and fruit and shade tree insects. Indeed, they must be considered from a different standpoint—that of prevention rather than that of destruction. Thus every separate trouble caused by different insects or the troubles caused by the same kinds of insects in different sections of the country must be studied separately with a view to determining methods of

utilizing some method of management specially adapted to the prevailing conditions in each case, which will reduce the number of the depredators or otherwise prevent losses.

SOME PRACTICAL RESULTS.

A few examples may be given of the practical application of a knowledge of some of the principal facts in the life history, as follows:

The recent determination that the tanbark-destroying insects do not attack the stored bark until it is two or three years old suggested a simple method of preventing losses.

The determination that the spruce-destroying beetle attacks only the larger trees, and that the beetles could be attracted to trees hack-girdled during the proper period in June, suggested important methods of forest management and lumbering operations, which will contribute to the elimination of trouble from this pest.

Girdling and timber-cutting experiments have demonstrated the possiblility of preventing losses from the ravages of insects and wood-destroying fungi by girdling and cutting timber when the physiological conditions are such as to render the bark and wood unattractive to the depredators or unfavorable for their destructive work.

A knowledge of the habits and characteristic work of bark-infesting insects in living, dying, and dead trees furnished conclusive evidence that a large amount of healthy, uninfested, living timber had been cut in the Black Hills forest reserve, where it was intended that none but trees infested by the pine-destroying beetle or those killed by it or other causes should be cut. It was also demonstrated that a knowledge of the principal facts relating to the primary and secondary insect enemies of the pine of this region would facilitate the drawing up of timber-cutting contracts which would avoid much future trouble and litigation relating to the interpretation of references to insect and insect-killed timber.

Facts determined relating to the habit of the pine-destroying beetle of the Black Hills and the relation of other insects and fungi to the trees injured and killed by it suggested methods of future management which would prevent the loss of much timber, and contribute to a better public appreciation of the importance of Government forest reserves and the adoption of scientific forestry.

The facts which have been recently determined from special investigations of the troubles caused by the destructive pine bark-beetle, the chestnut timber worm, the oak timber worm, the giant root-borer, and a number of other principal enemies of Eastern forest trees have made available a fund of information which it is believed can be used to special advantage in formulating future plans for the management of Eastern forest reserves, systematic forestry work, conservative lumbering, etc.

The new facts determined during recent investigations in California, Oregon, Washington, and Idaho relating to the habits of the destructive enemies of the redwood, Monterey pine, Western yellow pine, sugar pine, Jeffery pine, shore pine, mountain pine, and lodgepole pine, and the Western hemlock, Douglas spruce, Englemann spruce, several species of fir, the Western larch, and Western cedars, have made available a fund of information which will be of special service in future studies of the enemies of the principal forest trees of the Western forest reserves.

The extent and magnitude of depredations by insect enemies of the forests and forest products of this country; the comparatively meager knowledge of the essential features in the life history, habits, and natural enemies of the principal depredators on which to base conclusions relating to methods of control or prevention; the possibility, as has been demonstrated, of future detailed investigations leading to the discovery of methods of preventing a large part of the losses; the facilities afforded in the extensive Government reserves and in large private areas where systematic working plans and forest management have been adopted, together with the information available from the results of investigations in this country and Europe, seem to warrant the recognition of forest entomology as a distinct branch of economic science.