PARASITES

OF THE

GYPSY AND BROWN-TAIL MOTHS

INTRODUCED INTO

MASSACHUSETTS.

WHERE THEY COME FROM.
WHAT THEY ARE DOING.
A GENERAL SURVEY OF THE WORK.

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UNDER THE DIRECTION OF

F. W. RANE, State Forester.

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INTRODUCTORY.

This bulletin is published by the State Forester in order that any of our citizens interested may have a definite and comprehensive knowledge of the work that the State of Massachusetts is doing in importing parasites and predatory enemies of the gypsy and brown-tail moths.

I am sure this bulletin will meet a cordial reception by many of our people, as it explains the various points often so difficult to propound in the short time at one's command.

The time has come when we should have a better practical working knowledge of the future care of our trees. We must look upon these moth depredations and their ultimate control in a rational manner. When forest fires are burning, we do not hesitate to put them out, realizing their great destructiveness if allowed to run at will. The enormous damage that these moths have done in eastern Massachusetts is appreciated only by those who have lived in the infested districts. We propose to have many strings to our bow in fighting these moths. The work of introducing parasites, thought by scientists to be of great promise, was begun in 1905 and has been vigorously pursued ever since. It has not been by any means an easy matter to secure them in sufficient quantities, and get them established in this country in large enough numbers, to secure the desired results. Each year, however, has improved on the past, until at present very effective work is in progress. More material was secured last year than during the whole time previously, and the coming year is even more promising. The gypsy moth itself was here a number of years before it became sufficiently abundant to be considered a pest. If it took the gypsy moth many years to get established, with all favorable conditions apparently at its bidding, we must not get over-impatient awaiting the results which are hoped for in the introduction of its natural enemies. This work, as this bulletin explains, is in better con-

dition and more promising from actual results at the present time than ever.

The State Forester cannot refrain from saying also that what Massachusetts is doing in this work is indirectly as important to the nation generally; for what is here accomplished will ultimately result in equal value throughout New England and finally elsewhere.

ACKNOWLEDGMENTS.

The work of writing and compiling the data in this bulletin was done by Mr. W. F. Fiske, agent and expert, Bureau of Entomology, United States Department of Agriculture, in charge of directing the technical work of introducing the parasites and predatory enemies of the gypsy moth and the brown-tail moth into Massachusetts. The headquarters for this work are at the State laboratory at Melrose Highlands.

When it was determined by the State Forester that the information contained in this bulletin would be appreciated by our people, a conference with Dr. L. O. Howard, the United States Government Entomologist, who has been our chief adviser in expending the State's money for this work, resulted in his delegating Mr. Fiske to the task. Mr. Fiske's manuscript was examined and approved by Dr. Howard.

We are therefore under obligations to both of the above-named gentlemen for their hearty co-operative efforts in our behalf.

F. W. RANE,
State Forester.

6 Beacon Street, Boston, Mass., March 15, 1910.

PLATE I.

Grounds of the Gypsy Moth Laboratory, showing Temporary Structures used in rearing Parasites of the Gypsy Moth and Brown-tail Moth.

Interior of One of these Structures, showing Trays for feeding Caterpillars.

PARASITES OF THE GYPSY AND BROWN-TAIL MOTHS.

NATURE OF INSECT PARASITISM.

It is probable that the total number of different species of insects which are native to Massachusetts is not far short of 10,000, if indeed it does not exceed this number. A large proportion of these are plant feeders, some of them sucking the sap, others eating the foliage, and others still boring in the roots, seeds or stems. A great many feed upon dead vegetable matter, or upon the lower plants, such as mushrooms and other fungi.

Several thousand, possibly half of the total, feed upon animals or upon dead animal matter, and by far the larger part of these prey upon other insects, — principally, but by no means exclusively, upon those which are plant feeders. It is largely through this continuous warfare that the plant-feeding insects are held in check, and prevented from increasing to such numbers as to become a menace to vegetable life in general.

The insects which subsist upon other insects may roughly be divided into two classes, according to the methods of their attack. The predatory, like the other predatory animals, wander about, attacking and devouring the weaker species or individuals. For the most part they are very catholic in their tastes, and will attack almost any other insect which they may chance to encounter in their favored haunts. The parasitic, on the contrary, are in most instances very closely restricted in the choice of their prey, and have a very different method of attack.

Instead of falling upon and devouring a weaker insect, they frequently attack and destroy those which are much larger and stronger in every way than themselves. This is accomplished by the deposition of an egg, or in some instances a living maggot, within or upon the body of the selected victim, or upon its food, or in some other situation. The young larva, hatching from the

egg (or deposited by the female parasite, for in quite a large number of them the eggs hatch within the body of the parent), ultimately becomes established within or upon the body of the other insect, which serves as host; and, although there is considerable variation in the ways by which this is accomplished, the end is the same.

Having become established, the young larva proceeds to feed upon the less vital portions of its victim, usually upon the fatty tissues, until it is nearly or quite full grown; then, from its point of vantage inside the body of its host, it kills it, devours all or such portions of its body as it desires, and later transforms to a pupa, which in turn produces an adult similar to that which made the original attack.

There is hardly a plant or shrub or tree which is not attacked in some portion by one or more species of plant-feeding insects. Some trees, like the oak and pine, support a very great variety, which are widely diverse in their habits, and each of which confines its attack to a limited portion of the tree. Those which bore in the bark, for example, are always different from those which feed upon the foliage or which are nourished by the seed. Similarly, there is hardly a single plant-feeding insect which is not attacked by one or more different parasites, each of which is limited in its attack to some stage in the development of the particular species which serves as host. The parasites which attack the caterpillars of a plant-destroying insect, like the gypsy moth, never attack the pupæ or the eggs; but there are other parasites which do attack these stages.

Plant-feeding insects very rarely attack more than a few sorts of plants or trees. Some, like the gypsy moth, are very general feeders, and will eat the foliage of pine and fir as well as of oak and birch; but the number which feed upon both pine and oak are very few, and even the gypsy moth displays a strong preference for the foliage of broad-leaved trees. There are a great many which will feed upon nothing but oak, and there are many which are even more restricted, and which are never found on more than one kind of oak. Exactly the same is true of the parasites: some are general feeders, and will attack a great variety of hosts; others are extremely particular in this respect, and will not attack, or, if they are forced to attack, their young

cannot develop upon, more than a very limited number of hosts. The great majority are thus closely restricted in their host relations, and the parasites which are most effective in controlling the increase of plant-feeding insects are generally of this character. It is on account of this that the many hundreds of different parasites of native caterpillars do not, and cannot, attack and control an insect like the gypsy moth, which is different in many respects from any native American insect.

NATURAL CONTROL OF THE GYPSY MOTH.

With the exception of the parasites, nearly every, and probably every, controlling agency which works to keep the gypsy moth within bounds in Europe and Japan is present in America. Mortality through catastrophic causes, such as storms and climatic changes, is heavy here, as it is abroad. It is probable that the birds, which destroy so many of the caterpillars, pupæ and moths, are equally effective in both Europe and America. Disease, induced through overpopulation, is more prevalent in some parts of Massachusetts than in those countries where overpopulation is not so apt to occur; and a multitude of predatory insects, notably, the bugs described by Mr. Kirkland in the report on "The Gypsy Moth," by Forbush and Fernald, render great assistance. So effective are these various agencies, that, taking the older infested section as a whole, the gypsy moth is practically at a standstill so far as permanent increase in numbers is concerned. Its numbers cannot be said to decrease to a noticeable extent, except as the immediate result of artificial repression, and it has reached its maximum possible abundance. If it had continued to increase at a rate of only twofold annually, it would by 1909 have been thirty-two times as common as it was in 1904 in tracts of woodland where artificial suppression could not be economically employed. This is obviously not the case.

Even in newly infested territory, where the controlling effect of starvation and disease is hardly or not at all apparent, an increase of six-fold annually[1] during the first few years is about all that is expected; and when it is considered that the number of eggs deposited by one female is frequently in excess of 500, it is at once evident that natural causes are responsible

[1] Forbush and Fernald: "The Gypsy Moth," p. 94.

for the destruction of a tremendous percentage. Five hundred eggs, developing into an equal number of males and females, would result in the deposition of 250 egg masses the summer following, or an increase of two hundred and fifty-fold. If only a six-fold increase in the number of egg masses results, it is evident that 244 of the females must be destroyed at some time during their life; in other words there is an approximate mortality of no less than 97.6 per cent. annually in Massachusetts, due to natural causes.

So, to reduce the number of survivors as to permit of *no* annual increase, on the average, in territory where the gypsy moth is not sufficiently abundant to become a pest, is the hope and aim of the work of parasite introduction. As already stated, there is no steady increase of the moth in the central most badly infested sections of the area of infestation; but the control brought about by famine and plague within this area is so exclusively dependent upon overpopulation, which is to say, upon a superabundance of the moth, as to make very probable a continuation of the present conditions for an indefinite period, unless some other factor becomes operative.

PARASITE INTRODUCTION IN THEORY AND PRACTICE.

If, as is believed by those who have the matter most at heart, the only important controlling agency which is lacking in America is the presence of the parasites which are such effective factors in its control abroad, the introduction of these parasites into America and their establishment here is all that is necessary to bring about the reduction of the gypsy moth from its present pre-eminence as a destructive pest to that of an innocuous or rarely noxious insect. The problem at first sight seems simple, but, like most undertakings, it develops complications in its practical solution.

Long before the work of parasite introduction was begun, all of the published records of European parasites and other enemies were well known to the Bureau of Entomology, which for years had been keeping track of such observations, and had accumulated a card catalogue with more than 20,000 references. As soon as work was begun, additional information concerning gypsy and brown-tail parasites was secured from European and

Japanese entomologists, who were most generous in their offers of assistance and advice. At the same time, it must be admitted that the sum total of available and absolutely reliable information was far from adequate. Long lists of parasites had been compiled[1] but these records were based upon the notes and observations of entomologists who were not particularly interested in the possible practical side of the question, and very frequently their records amounted to little more than the bare fact that a certain parasite had been reared in connection with the gypsy moth or the brown-tail moth. Furthermore, the same parasite was sometimes referred to by different entomologists under different names, or different parasites were considered to be the same, and on this account hardly any dependence could be placed on many of the records, and the doubt was reflected upon others. With very rare exceptions, nothing was published which gave any clue to the relative importance of the different species, and in several instances a secondary parasite was recorded as attacking the gypsy moth itself.

The work in the beginning was largely experimental, being an effort to determine ways and means for securing the parasites in a living and healthy condition. This accomplished, it became necessary to make a critical study of the various species secured, to determine, first of all, whether they were truly primary enemies of the moth, or whether they were present in some other connection. If they proved to be primary parasites and true enemies of the gypsy moth, they were liberated as rapidly as they could be imported and reared. As the work progressed, the various species were studied in greater and greater detail, and were ranked according to their relative importance in the countries to which they were native, and according to their methods of attack. Every effort was made to learn the main facts in the life and habits of each, and to become familiar with the conditions necessary to insure the establishment of each species in Massachusetts.

Upon numerous occasions knowledge of this character has been of the greatest value in suggesting the methods of importing, handling and colonizing the parasites, and in some instances it was essential to success. The work has been seriously handi-

[1] Howard: "Insect Life," vol. 2, p. 210. Forbush and Fernald: "The Gypsy Moth," pp. 377 and 387.

capped through the practical necessity of entrusting the actual work of collection and shipment in foreign countries to others than those most familiar with the nature and needs of the various parasites. The several trips which Dr. Howard has made abroad, wholly or in part in the interest of this undertaking, has enabled him to meet the foreign agents, and to enter into explanations which were infinitely more satisfactory than any which could be effected through correspondence. At the same time, it has been impossible to convey to these agents the detailed information which would enable them to work to the best advantage, nor would it be possible for them to acquire this in any manner short of actual experience in the laboratory. In particular has it been handicapped by the very short period during which work upon any particular parasite could be carried on in any one year. Parasites of the pupa, or of certain stages of the caterpillars, could be collected in Europe or Japan only during the season when pupæ or caterpillars in those particular stages occurred in the open in those countries; and the aggregate period during which it has been possible to work with some parasites in the five years since the inception of the work does not exceed as many months.

In all, there have been received at the laboratory in a living condition between 40 and 50 species of parasites of the brown-tail moth and of the gypsy moth. Of these, about 30 attack the gypsy moth, but only about two-thirds of that number can be considered as at all important. The others seem always to be rare in the countries to which they are native, and never to become so abundant as to affect the increase of the moth. No parasite, however rare it might seem to be, has been ignored, once it was demonstrated to be a primary upon the gypsy or the brown-tail. A great deal of time has been spent in attempting to discover the probable reason for apparent inconsequence in so many instances; and a great deal of work has been done to demonstrate that this was due to other causes than defective methods in the collection and subsequent handling of the parasite importations.

One by one, as material has been imported under different conditions and from different countries, different species of parasites have been added to the list, until it has exceeded in

gross numbers any list of parasites of the gypsy moth which has ever been published. One by one, as these parasites have been received and studied, they have been rated according to their habits and importance in the countries from which they came, and those which have failed to show promise of ever becoming of value in America have been eliminated. One by one, different species have been liberated in America under the most favorable conditions which could be provided for their establishment, until at the present time there are only 3 or 4 out of a total of 20 (which may be considered as including all of the promising parasites of the gypsy moth in Europe and Japan) which have not been liberated here, or which are not on hand ready for liberation as soon as the proper season shall arrive. The others, tentatively considered as of possible value, are very rarely common in any country; and partly on this account, and partly on account of the extraordinary difficulties which stand in the way of their successful importation, it has been impracticable to determine whether they are to be ranked as promising, or not. It is very likely that they will prove to be of a distinctly minor importance when they shall have been thoroughly investigated.

SEQUENCE OF PARASITES.

There is one very important factor which must be taken into consideration and thoroughly understood before it will be possible intelligently to discuss the work which has been accomplished in the importation of parasites of the gypsy moth. Briefly stated, it is that no one parasite is capable of effecting the necessary amount of control in an insect of the character of the gypsy moth, and capable of a similarly rapid rate of increase when unchecked by parasites; but a sequence of parasites, which will attack the insect in different stages of its development, and all the component members of which will work together in harmony, is absolutely necessary before the best results may be expected.

It has already been stated that the different parasites of one host are limited in their attack to certain stages in the development of this host. In the case of the gypsy moth, there are some which attack the egg, others the young caterpillars or the

older and larger caterpillars, and those which form still another group reserve their attack until such time as the caterpillars have spun up preparatory to their transformation into pupæ, or until after this transformation has taken place. It is confidently believed that representatives of each of these three or four groups will have to be established in America before any marked results of a practical nature can be expected.

There are two exceedingly good reasons for believing this, which may be mentioned here besides others equally good, but less easily expressed in non-technical language. One of these is the fact that in not a single instance has one species of parasite been found sufficiently abundant abroad to bring about the percentage of destruction which will certainly be necessary in order to offset the six-fold rate of increase of the gypsy moth, which it is the consensus of opinion exists in newly infested territory in America at the present time. The other is, that there is not a single species of defoliating caterpillar, similar in habit to the gypsy moth, of which the parasites have been studied, and which is controlled by them to any extent, which does not support a sequence of parasites similar to that which it is proposed to establish for the gypsy moth.

If the theory as to the necessity of a sequence of parasites be accepted as a general rule, its importance cannot be overestimated. Success in the work of parasite introduction will then depend entirely on whether or not a sufficient variety of parasites can be established in America, and cannot obtain until all of the species which go to make up a natural and effective sequence are established, and have increased to a sufficient abundance to make each of the chain effective in its own particular field. The predaceous beetles alone can never bring about the desired end, neither can the egg parasites, nor those of the pupæ, nor, it is believed, can all these three groups together. The parasites of the caterpillar, in addition to these others mentioned, ought to bring about the desired end. The Calosoma beetles bid fair to assist the native predatory enemies materially in the good work which they are doing, and their establishment will make that which is expected of the parasites easier and more certain of accomplishment.

It ought to be stated, in this connection, that this principle,

Large Shipment of Parasite Material received in 1909 from France.

Gypsy Moth Laboratory, Exterior. Lot of Packages of Parasite Material just received.

while it has been recognized as one applicable in many instances, has been established much more firmly than ever before, as a result of the work which has been done at the laboratory. It would be impossible to speak with so much assurance had it not been for a series of investigations upon the parasites of several native insects, similar in certain important respects to the gypsy moth. These investigations have seemed sometimes to be outside of the main point at issue; but their value in establishing, as they have, this and certain other general propositions, has justified many times over the relatively small expenditure necessary to carry them on.

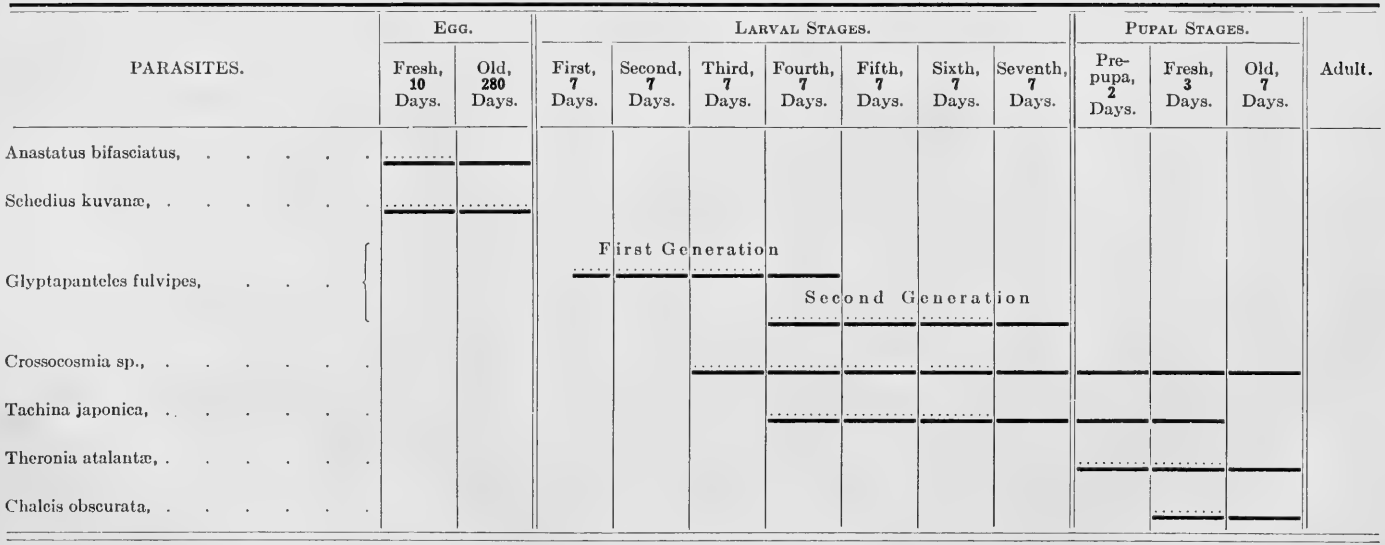
PARASITES OF THE GYPSY MOTH IN JAPAN.

The Japanese race of the gypsy moth is larger and stronger and in certain other respects different from that found in Europe or in America. One important characteristic is its greater fecundity, the number of eggs in a mass being from one-fourth to one-third greater, on an average, than in the egg mass of the typical European variety. This is indicative of greater powers of resistance to natural controlling factors, and, conversely, of the existence of more effective controlling agencies in Japan than in Europe. It is very significant that it is not at all an important pest in Japan, and that, in the opinion of the native entomologists and of every American entomologist or otherwise trained observer who has had opportunity to acquire first-hand information, the parasites are very effective in its control.

Thirteen species of primary parasites have been reared from eggs, caterpillars or pupæ of the gypsy moth from Japan, but only 7 of these can be considered as of importance in bringing about its control. The others have been consistently rare, and some of them have never been recorded as parasites by the Japanese themselves.

These parasites, in every instance but one, are either identical in all respects, or, if not absolutely the same, exceedingly similar to the parasites in Europe. It is unfortunately necessary to refer to them by their technical names, since none of them have been considered as of general interest hitherto, and other than such names there are none. They are listed in Table 1.

TABLE 1. — *The Gypsy Moth. — Sequence of Parasites in Japan.*



How they work in effecting the control of the moth in their native country is best indicated in the table, which, while it needs explanation, tells the story much plainer than it would be possible to tell in words. Opposite the name of each parasite, extending across a certain number of the vertical columns, is a dotted and a solid line. The vertical columns indicate different stages in the development and transformations of the gypsy moth, as egg, caterpillar and pupa, and these are still further divided into caterpillars of different sizes and eggs and pupæ of different ages and conditions. At the head of each column is stated the approximate number of days during which the individual gypsy moth remains in that particular stage.

The dotted line following the name of the parasite indicates those stages in the life of the gypsy moth during which it is liable to be attacked by the parasite in question, and it will be seen that in a number of instances, as, for example, Chalcis and Theronia, this period is exceedingly short. The solid line indicates the stages in the life of the gypsy moth during which it is likely to contain the parasite in its body. This, it may also be noted, varies considerably. Crossocosmia, for example, gains lodgment in the active caterpillar while it is only about half grown, and the extension of the solid line across all of the columns which stand for the later caterpillar stages, as well as for all of the pupal stages, indicates that the larvæ of this parasite do not leave the host caterpillar until after it has transformed to a pupa, and until the moth would naturally have emerged had the pupa remained healthy and unparasitized.

The main fact, which it is particularly desired to emphasize, is that every stage in the transformations of the gypsy moth, from the time the eggs are first deposited until the caterpillars are full grown and transformed to pupæ, is subject to the attack of one or more parasites. It is also liable to attack at any time throughout this period except during the cold weather in the winter, when there is no insect activity. This is exactly what is meant by the sequence of parasites, and, in the opinion of those most thoroughly informed, it is the condition which it is absolutely necessary to bring about in America before complete control can be effected.

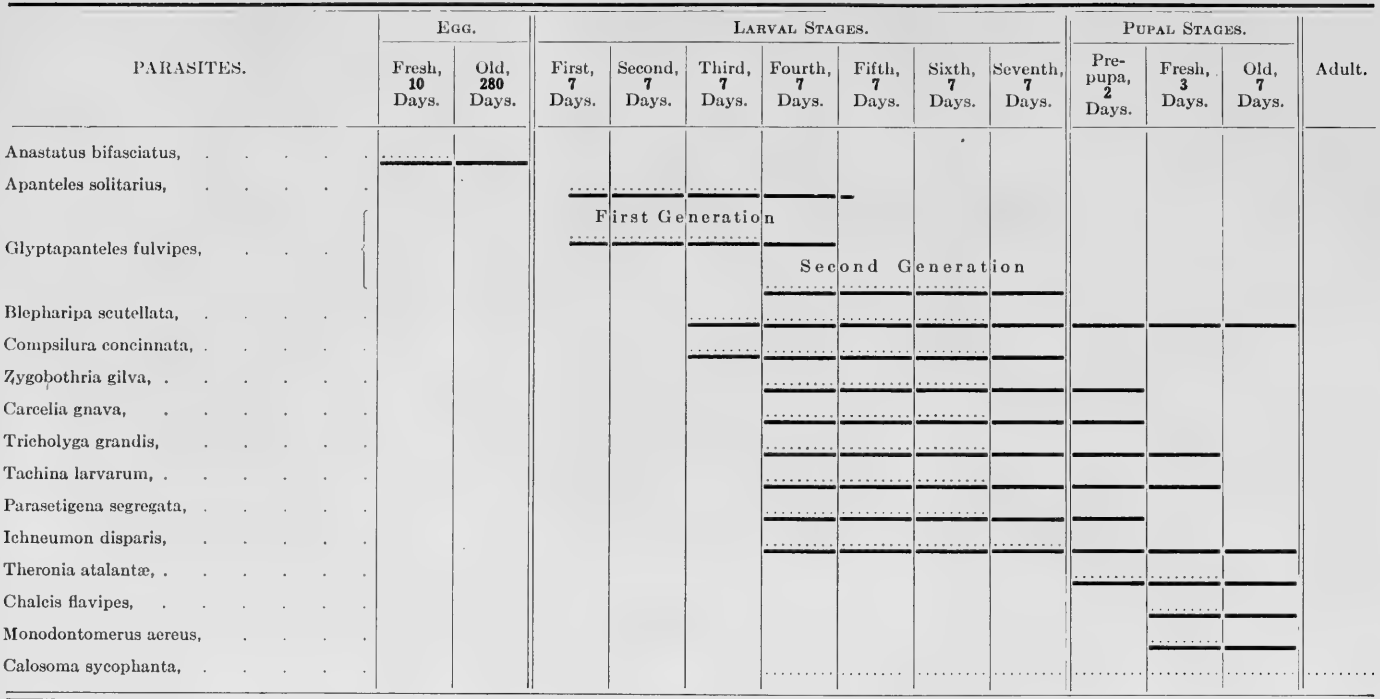
PARASITES OF THE GYPSY MOTH IN EUROPE.

Table 2 is similar in construction and illustrates the parasitism of the gypsy moth in Europe. There are at least 22 species, and possibly one or two more of slight importance, known to attack the moth in various European countries, and of these, 15 are considered to be important. Of the 22, 2 are identical in all respects with 2 which occur in Japan, and are considered to be the same species. Six or 7 are quite distinctly different from any which have yet been received from Japan, and it is impossible to separate the remainder from the Japanese species by habit and method of attack alone. The most of them, however, appear to be different in their final appearance as adults, and are considered, for the present, as representing different species.

There are several reasons why there should be a longer list of European than of Japanese parasites, principal among which is the greater variety of climate represented by the different European countries. Some of the parasites are confined almost exclusively to the Mediterranean region, others to Russia and eastern Europe generally, while others are more common in the northern, central and western portions. It is almost certain that other parasites will be found in other parts of the Japanese empire from which small quantities of parasite material have been received, but it is very doubtful if any of importance will be added to the list from European sources.

It will be noted, if the table is scrutinized, that exactly the same conditions as regards the sequence of parasites obtain in Europe as in Japan. As in the table first given, every stage of the moth from the newly deposited egg to the pupa is open to attack by one or more species of parasite, and the sequence is perfect.

TABLE 2.—*The Gypsy Moth.—Sequence of Parasites in Europe.*



PARASITES OF THE GYPSY MOTH IN AMERICA.

There is just one parasite of the gypsy moth in America, native to the country, which ranks in importance with the least of those included in the tables of Japanese and European parasites. This is Theronia, and the native species is so similar in habit as to be indistinguishable from the other species of the same genus which attack the same host in Europe and Japan, and it cannot as yet be stated with assurance that it is not the same. It is literally the least important of all of the parasites listed, and the maximum effectiveness in America is, if anything, less than in any foreign country. It cannot be credited with destroying more than 1 in 30 or 1 in 50 of the pupæ, on the average, and never more than 1 in 10 under the most favorable conditions ever observed. A table of the native parasites of the gypsy moth (leaving out the rare and inconsequential species), prepared for comparison with those of the European and Japanese, would consist of this species and no other, and the difference is obvious.

In Table 3 are listed all of the parasites which have been received from Europe or Japan in sufficient numbers to make possible satisfactory colonization in America. There are 4 or 5 more which have been liberated in small numbers, or which are on hand ready for liberation in the spring, including *Tachina japonica* and *Chalcis obscurata*, Japanese representatives of the European species, and having nearly identical habits. There are also on hand at the laboratory a large number of the hibernating puparia of *Parasetigena segregata* and *Crossocosmia* sp., both of which are parasites of some promise, and neither of which has yet been colonized.

TABLE 3. — *The Gypsy Moth. — Sequence of Parasites in America.*

PARASITES.	EGG.		LARVAL STAGES.							PUPAL STAGES.			ADULT.
	Fresh, 10 Days.	Old, 280 Days.	First, 7 Days.	Second, 7 Days.	Third, 7 Days.	Fourth, 7 Days.	Fifth, 7 Days.	Sixth, 7 Days.	Seventh, 7 Days.	Pre-pupa, 2 Days.	Fresh, 3 Days.	Old, 7 Days.	
Anastatus bifasciatus,													
Schedius kuvanæ,													
Glyptapanteles fulvipes,			First Generation			Second Generation							
Blepharipa scutellata,													
Compsilura concinnata,													
Zygobothria gilva,													
Carcelia gnava,													
Tricholyga grandis,													
Tachina larvarum,													
Theronia fulvescens,													
Chalcis flavipes,													
Monodontomerus aereus,													
Calosoma sycophanta,													

It is not by any means assured that all of these parasites are established here, but it is possible that they are, or that they will be before another season passes. Some that are known to be living in the field, and which are apparently in a very good way toward becoming permanent fixtures in the American fauna, have had their freedom for less than one year; and there is no assurance that a species is established until it has completed at least one cycle of the seasons unprotected in the open. A few of them, as will be shown later, will be the better for artificial assistance in dispersion, etc. One, Chalcis, ought to be imported in larger numbers, but with this one possible exception, each that is listed has been liberated under the most favorable circumstances which it is possible to provide.

Especial attention is called to the fact that the sequence is complete as it stands. Every stage of the moth is provided with a parasite which will attack it, if given the opportunity, and in every respect the table compares favorably with that illustrative of the Japanese parasites or of the European. It represents, in this most important respect, the climax of the endeavors of the past five years, and it has been accomplished only during the past five months. If the writer were assured of the firm establishment of each of the species listed, and that each would become as efficient in Massachusetts as it is in the countries from which it came, he would state without reservation that the work of parasite introduction was successfully accomplished.

The reader must not confuse the accomplishment of parasite introduction with the accomplishment of the end which it is desired to achieve. It goes without saying, when the habits of the parasites are taken into consideration, that the few paltry thousands, which it has been possible to secure through methods of importation which were the best which experience could devise, must be allowed sufficient time to increase to the millions and billions necessary to cope with the tremendous quantities of gypsy moths which are everywhere in evidence throughout the infested district, wherever the expensive methods of hand suppression have not been employed.

Fortunately, this increase, if it follows colonization, will be by geometrical progression, exactly as has been the case with the gypsy moth; and it will, most fortunately, be much more rapid

FIG. 1. — *Anastatus bifasciatus:* gypsy moth egg parasite, adult female, greatly enlarged.

FIG. 2. — Anastatus: egg, greatly enlarged.

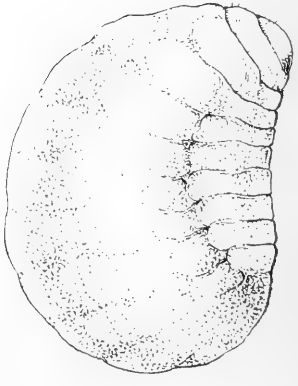


FIG. 3. — Anastatus: hibernating larva from gypsy moth egg, greatly enlarged.

than it was in the case of the gypsy moth, owing to the greater dispersive powers of nearly all of the parasites. With one exception, they more nearly resemble the brown-tail moth in this respect, being gifted with the power of flight; and, as is well known, the territory covered by this insect is much more extensive than that covered by the gypsy moth, although the latter was introduced into America more than twenty years earlier.

Another enormous step in advance, which has marked the progress of the work the present season, is the accumulation of certain valuable data which throw much-needed light upon the subject of parasite dispersion, and which have tended more than anything which has come about since the earliest beginning to encourage those who have been charged with direction of the work. For the first time it is possible to calculate, with some foundation upon fact, the probable outcome of the undertaking. It is difficult to do this on the small amount of absolutely authentic information at hand, and to vouch for the accuracy of the conclusions with any degree of assurance; but the attempt has been made, and will appear in the concluding paragraphs.

First, in order to make more clear the ground which supports these conclusions, a brief account of each of the introduced parasites of the gypsy moth will be given. No attempts have been made to go into technical detail concerning the lives and habits of these several species, further than is necessary to give a general idea of their methods of attack, and of the hopes and fears which are felt for the future of each.

Parasites of the Egg.

Anastatus bifasciatus.

This minute parasite (Fig. 1) attacks the newly deposited eggs of the gypsy moth during the brief interval which elapses before the embryonic caterpillars develop. Its eggs (Fig. 2) are deposited singly, one in each individual egg of the host, and its larvæ feed upon the substance of the host eggs and become full fed in about three weeks. They then enter on a long resting stage, snugly ensconced within the limited confines of the

shell (Fig. 3), and do not resume activity until the middle of the following summer, ten months later. The transformations to pupa (Fig. 4) and adult (Fig. 1) follow in the course of two or three weeks, the latter emerge, and in a few days are ready to deposit eggs for another generation within the newly deposited eggs of the next generation of the gypsy moth. There is thus but one generation of the parasite each year, and its life cycle, which corresponds to the annual cycle, is correlated exactly with that of the insect which serves as its host.

It is a native of both Europe and Japan, and is sometimes a common and effective parasite in either country. It is very unevenly distributed, however, especially in Europe, and a great many lots of eggs have been received which did not contain any of the parasite. For two years large numbers of egg masses were imported from various European and Japanese localities, and not a single specimen was secured. Finally, in the spring of 1908 it issued almost simultaneously from Russian and from Japanese eggs, and was soon determined to be a primary parasite. About 500 individuals were liberated that summer, but under conditions which were unsatisfactory in many respects, and no reproduction in the field resulted, so far as has been determined.

Encouraged by the knowledge that there was an egg parasite which could be secured through the winter importation of eggs, — a fact which was far from being established up to the rearing of the first specimens of Anastatus, — larger importations from numerous localities were made during the winter of 1908–09. As before, only a part of these shipments were productive, but among them was one consisting of five sacks of about 1,000 egg masses each, from Professor Jablonowski of Budapest, which were collected in five different Hungarian localities. From three of these only an insignificant quantity of parasites was secured, one lot being entirely unparasitized. From two, however, was secured by far the largest number of egg parasites ever received from any source, there being more than 80,000 all told. It illustrates very well the uneven distribution of the species in Europe.

These, together with some others from other sources, were liberated in five colonies, in quite widely separated localities

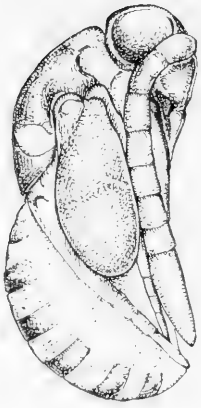


FIG. 4. — Anastatus: pupa from gypsy moth egg, greatly enlarged.

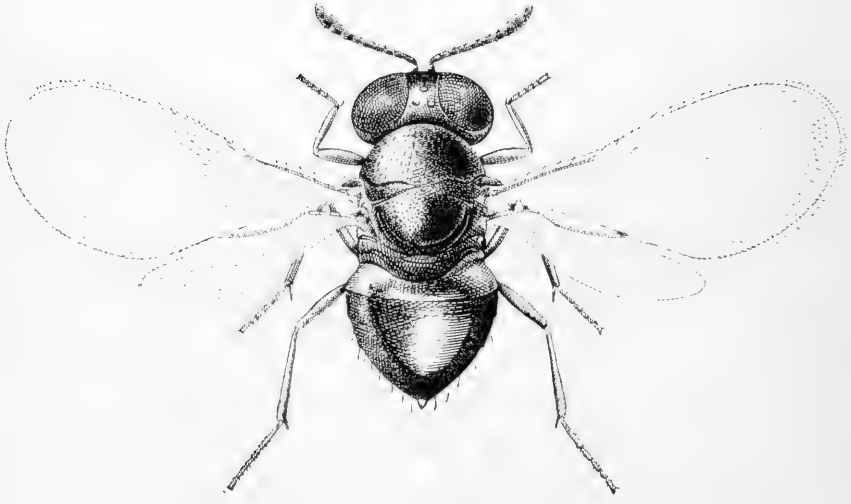


FIG. 5. — *Schedius kuvanæ*: Japanese parasite of gypsy moth eggs, adult female, greatly enlarged.

within the infested area. In every instance they attacked the freshly deposited eggs of the moth with avidity, and reproduction in the field under perfectly natural conditions resulted. At the present time there are many thousands of the larvæ of the parasite hibernating in the open in the immediate vicinity of the colonies, exactly as they would do in their native land, and there is hardly room to doubt that they will issue next summer in the normal manner.

In one respect only is the insect disappointing. It appears to resemble the gypsy moth, in that the females do not fly. The utmost endeavors have been made to determine accurately the distance to which it travelled from each of the points where it was liberated, and the results indicate that 100 feet is about the limit. This is a rate of dispersion slower than that of the gypsy moth itself, and it would take a great many years for the parasite to spread over the entire infested area. Additional importations will be made during the present winter, and it is hoped that a large number of colonies will be established next summer, but no immediate benefits can be expected.

Schedius kuvanæ.

Most fortunately it is not necessary to depend exclusively upon the Anastatus as a parasite of the eggs of the gypsy moth, for in Japan there is another (Fig. 5) with similar habits, in so far as the object of its attack is identical; outside of this fact, it is different in many important particulars. Instead of confining its attack to the freshly deposited eggs, it rather prefers those in which the embryonic caterpillars have developed, and, since these caterpillars are fully formed, and so far as appearances go ready to hatch within three weeks after the eggs are deposited in the summer, Schedius is actually a parasite of the unhatched caterpillar, rather than of the egg. Instead of requiring a full year to complete the life cycle from egg to adult, it completes a generation once every three or four weeks during the warmer part of the summer, or in the winter if kept in rooms properly warmed. It is thus able to go through at least two generations during the fall, after the eggs of the moth have been deposited, and before cold weather puts a stop to its activity.

The history of its introduction into America is most interesting, and, except for the fact that it was so long delayed in execution, forms one of the most satisfactory episodes in the entire work of parasite introduction.

As long ago as the spring of 1907 a few dead adults were secured in an importation of gypsy egg masses received during the winter from Japan, but none were living on receipt. During the winter next following larger importations were made, and many thousands of eggs, from which some parasite had issued, were found, but not a single living specimen was obtained. It was evident that it completed its transformations and issued in the fall, and that, if it hibernated in the eggs, it was warmed to activity while the packages were in transit to America, and the adult parasites either died or escaped en route.

In the fall, winter and spring of 1908–09 a large quantity of eggs of the gypsy moth were received from Japan, the shipments beginning early in the fall and continuing until nearly time for the caterpillars to hatch in the spring. The first, received in September, contained hundreds, possibly thousands, of the parasites, which had issued from the eggs en route, and all of which, as usual, had died; not a single living individual was received. Specimens were referred to Dr. Howard, who found that they represented an entirely new and hitherto undescribed species, which he named after Professor Kuwana, who collected and sent the eggs from which they had issued. A single pair of living specimens rewarded the careful attention which was lavished upon the importations received later in the fall and during the winter, and it was not until April, 1909, that a mated pair could be secured. During that month a total of 11 individuals issued from cages containing Japanese eggs recently received.

This small number served as the beginning of a series of experiments in propagation, which succeeded so well that in August several thousands were available for liberation in the field. In September and again in October additional colonies were established, and during the fall, some 50,000 in all were given their freedom.

After September the bulk of those reared were kept for extensive propagation work in the laboratory, and at the present time (February 1) a conservative estimate of the number in various

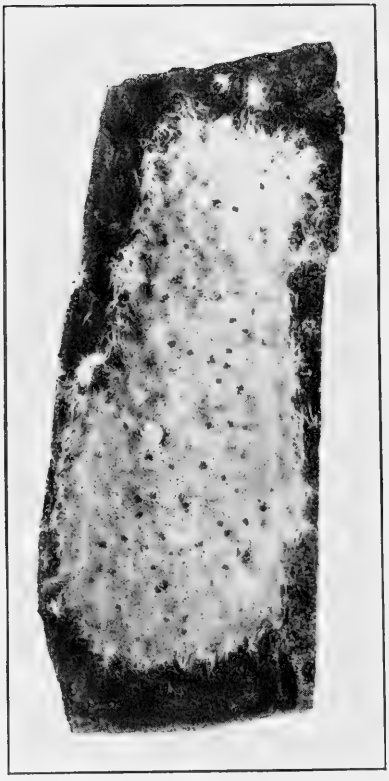


FIG. 6. — Gypsy moth egg mass, showing exit holes of Schedius, enlarged about four times.

stages in the reproduction cages is 2,000,000. It is by no means sure that the species will go through the winter in the open as successfully as is hoped will be the case; but no obstacle threatens to prevent the liberation of several millions of the parasite during the summer of 1910.

The reproduction of the parasite in the field, as a result of the earlier attempts at colonization, has been far in excess of expectations. The rate of reproduction in the laboratory, which averages only about ten-fold each generation, was greatly exceeded, and hundreds of thousands of eggs were known to be parasitized in the immediate vicinity of the colony sites. In the one colony which has been most carefully watched the parasitized eggs (Fig. 6) average some 30 to the mass everywhere within a radius of 50 yards, and the masses in a few places are so thick as to hide the bark on the trees. Beyond 50 yards the numbers fall off very rapidly; but the species has been found several hundred yards from the point of liberation, in striking contrast to Anastatus, which traveled only 100 feet.

It is hoped that a strong colony will be established in every town in the infested district during the coming summer; and if the same rate of dispersion indicated during the past fall continues, and the parasite demonstrates its ability to exist under American conditions during the entire year, it should be generally established throughout the infested area in two or three years more.

It must not be forgotten, however, that it has not yet proven itself adaptable to American conditions at all seasons. Like the other egg parasite, Anastatus, the only known host is the gypsy moth; but, unlike that species, its life is not correlated to that of its host. It is not known how it passes the winter, and, although living adults issue within a few days from egg masses brought in from the vicinity of the colonies in December, it is possible that they will not survive the cold weather which is bound to follow in January and February.[1] There is also a possibility that in Japan there is some other sort of egg subject to its attack, in which it passes a generation during the early

[1] This statement was written in December. It has since been found that all of the larvæ and pupæ of the parasites perished during the cold weather in January, but that adult parasites, of which there are known to be many in the field, lived through it. Whether they will survive the remainder of the winter is yet to be demonstrated.

summer, before the eggs of the gypsy moth are available, and that there will be no native insect which will give what may prove to be some such necessary aid to its continued existence.

Parasites of the Caterpillar.

Glyptapanteles fulvipes.

Although this was almost the first parasite of the gypsy moth which attracted any attention in Massachusetts, and the first which it was attempted to import after the beginning of active work, it was one of the last to be liberated under satisfactory conditions, and its establishment in America is not yet certain. Extraordinary methods were necessary to bring it to America living and healthy, and it was not until Prof. Trevor Kincaid, who was selected by Dr. Howard as the best available man for the purpose, visited Japan, and personally superintended the collection and shipment of the cocoons, that success was achieved. The story of Professor Kincaid's experiences and of the difficulties which he met and overcame is interesting. He was accorded great and material assistance by the Japanese entomologists, and the work inaugurated by him in 1908, was continued with even greater success in 1909.

The adult parasite (Fig. 7) deposits a number of eggs beneath the skin of the active caterpillars, and any stage, from the first to and possibly including the last, may be attacked. The larvæ, hatching from the eggs, become full grown in from two to three weeks, and then work their way out through the skin of the still living caterpillar (Fig. 8) within the body of which they fed. Each spins for itself immediately afterward, for its better protection during its later stages, a small white cocoon. The number of parasites nourished by a single host varies in accordance with its size. There may be as few as 2 or 3 in very small caterpillars, or 100 or more in those which are nearly full grown.

The unfortunate victim of attack does not, as a rule, die immediately after the emergence of the parasite larvæ and the spinning of their cocoons, but it never voluntarily moves from the spot. Its appearance, both before and after death, surrounded by and seeming to brood over the cocoons, is peculiar and characteristic, and once seen can never be mistaken (Fig. 9).

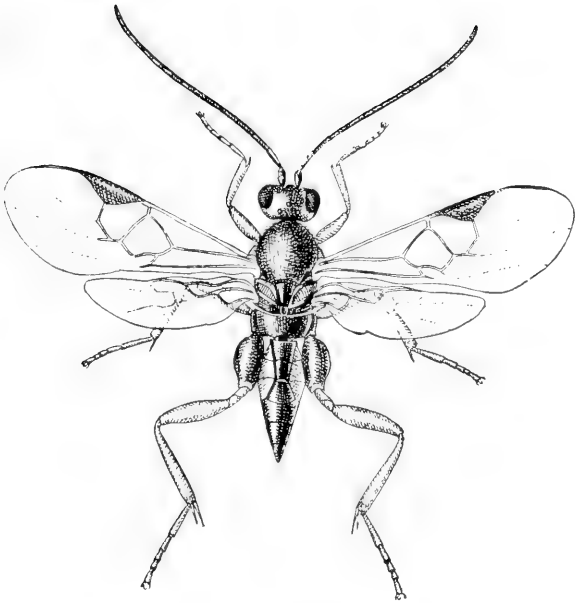


FIG. 7. — *Glyptapanteles fulvipes:* Japanese and European caterpillar parasite, adult, greatly enlarged.

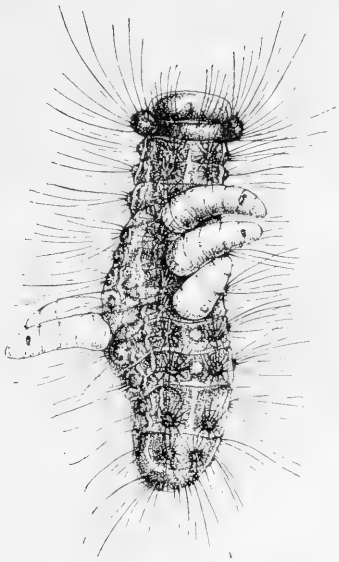


FIG. 8.—Glyptapanteles: larvæ leaving gypsy moth caterpillar, enlarged.

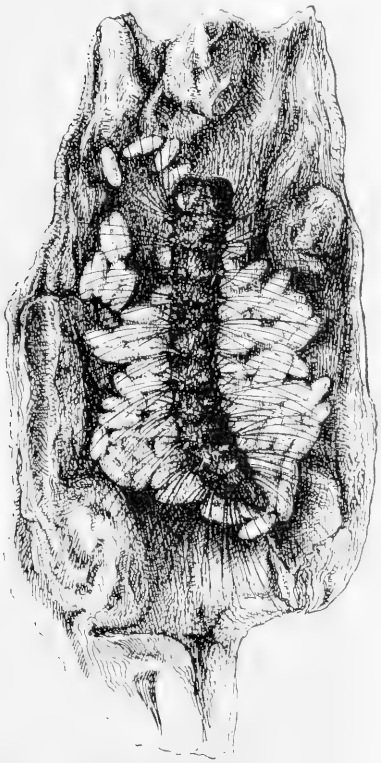


FIG. 9.—Glyptapanteles: dead gypsy moth caterpillar surrounded by cocoons of parasite, slightly enlarged.

There is ample opportunity for two generations of the parasite annually upon the caterpillars of one generation of the gypsy moth. This is the rule in the countries to which it is native, and is to be expected in America.

The parasite was described from Europe more than seventy-five years ago, and has been known to be a parasite of the gypsy moth for a long time. Later it was described under a different name from Japan, and the Japanese parasite was for a time considered to be different from the European. Absolutely no differences in life and habit which can serve to separate the two are known, and, as the adults are also indistinguishable in appearance, they are considered to be identical.

It has been the subject of frequent mention under the name of Apanteles, as well as of Glyptapanteles, in the various reports of the superintendent of moth work, from the first to the fourth; and Dr. Howard, in the account of his first trip to Europe in the interests of parasite introduction, tells of its occurrence in the suburbs of Vienna. Largely on account of the fact that it is much more conspicuous than many of the other parasites, it has attracted more general attention. The Rev. H. A. Loomis, a missionary, and resident of Yokohama, was the first to call attention to its importance in Japan, and made several unsuccessful attempts to send it to America. Dr. G. P. Clinton, mycologist of the Connecticut Agricultural Experiment Station, who visited Japan in 1909, observed the parasite at work, and reported most favorably upon its efficiency as a check to the moth. Numerous other attempts on the part of European and Japanese entomologists, including one elaborate experiment, which involved the shipment of a large wire-screened cage containing a living tree with gypsy caterpillars and the parasite, were made, but with uniformly ill success. Upon every occasion the parasites all emerged from their cocoons and died en route.

When every other means failed, Professor Kincaid, as already stated, was deputed to visit Japan, and to make all necessary arrangements for the transportation of the parasite cocoons in cold storage to America. The arrangements which he perfected provided for continuous cold storage, not only en route across the Pacific, but during practically every moment from the time

the cocoons were collected in the field in Japan until they were received at the laboratory in Melrose. Events justified the adoption of every precaution, and, with all the care, only a small part of the very large quantity of cocoons which he collected reached their destination in good condition. Hundreds of thousands were collected and shipped, and less than 50,000 were received alive, — nearly all in one shipment in July.

The season in Massachusetts was early, and nearly all of the gypsy caterpillars had pupated by that time, so that there was no opportunity for the parasite to increase in the field upon this host that season. In 1909 the sites of the colonies were frequently visited, but not a single parasitized caterpillar was found which could be traced to colonizations of the year before. Keen disappointment was at first felt, but later developments have tended to throw a more encouraging light upon the situation.

In 1909 importations were continued, through the magnificent efforts of Prof. S. I. Kuwana of the Imperial Agricultural Experiment Station, at Tokio, with much more satisfactory results. In 1908 the season in Japan was very late, and it was not practicable to send any of the cocoons of the parasite until June and July; while in America the season was early, and by that time all of the caterpillars, as has already been stated, had pupated. In 1909 the season was rather early in Japan and correspondingly late in America; and besides, through special effort, Professor Kuwana was enabled to send a few thousands of the cocoons of the first generation, which reached the laboratory early in June. About 1,000 adults emerged from these cocoons after receipt, and the most of them were placed in one colony in a cold situation on the North Shore, where the caterpillars were greatly retarded, and where there were still some in the first stage. The remainder were colonized in warmer localities, where the caterpillars were one stage farther advanced.

Immediate success followed the planting of these colonies. Within three weeks cocoons were found in each, and the number of parasitized caterpillars was gratifyingly large. A very careful investigation was conducted, to determine the proportion which was attacked by native secondary parasites; and, while this was so very large in one instance as seriously to jeopardize

the success of the experiment, it was not so large in the others.

There were several thousands of this first generation known to have developed in the open upon American soil, which issued from the cocoons some four or five weeks after the colonies were established, but in only that one on the North Shore, where the caterpillars were in the first and second stages when the parasites were liberated, was there a full second generation. Here the larger caterpillars were again attacked, and an abundant second generation of the parasite followed.

Meanwhile, additional shipments of cocoons of the second Japanese generation were received early enough to permit of a generation in the open upon the native caterpillars, and several other colonies were successfully established. It is known that there were many thousands of the parasite issuing in at least five different localities during August, but immediately thereafter they were completely lost to sight, and it is futile to hope to recover traces of them before another spring.

Until the late summer of 1909 nothing occurred to indicate that this parasite would be likely to fly for any great distance from the point of its liberation; and, as has been already stated, it was looked for in vain in the summer of 1909 in the immediate vicinity of the colonies of the year before. In July, 1909, a strong colony was planted in an isolated woodland colony of gypsy moths in the town of Milton. It was rather confidently expected that it would attack these caterpillars so extensively as to destroy the major portion; but it was the cause of some surprise, when the locality was visited after the parasites of the new generation had mostly issued from the affected caterpillars, to find a smaller number of cocoons than there were individuals liberated in the first place, and only about one-fourth, perhaps less, of the caterpillars attacked. The circumstance was as discouraging as anything which had gone before, and for a few days nothing happened to change its complexion. Then, to the intense surprise of the writer, Mr. Charles W. Minott, field agent of the central division, sent to the laboratory a *bona-fide* example of the parasite, which had been collected in the Blue Hills reservation, upwards of a mile away. There was no possible source except the Milton colony, and a spread of upwards of a mile in something under a week was indicated beyond dis-

pute. At almost the same time the brood of Monodontomerus was found for the first time in pupæ of the gypsy moth in the field; and when the history of this species is considered, in the connection which it bears toward the circumstances surrounding the recovery of the Glyptapanteles so far from the point where it was liberated, the whole situation is altered.

Granted that the parasite disperses at the rate of one mile in each week of activity, and that it is able to adapt its life and habits to the climate and conditions in America, the chances are, that, instead of looking for it in the immediate vicinity of the points of colonization, it is quite as likely to be found almost anywhere in the infested area within 25 miles of Boston. If it is thus generally distributed, very large numbers in the aggregate may exist, and it may increase at a rate as rapid as that of Monodontomerus, and at the same time escape detection until the summer of 1911 or 1912.[1]

This is not only possible, but probable, unless a number of careful observers assist in the recovery of the parasite next season; and if any one should chance, at any time during the summer, to discover parasite cocoon masses similar to those figured, and will collect them and forward them in a small box to the gypsy moth laboratory, Melrose Highlands, Mass., the service will be greatly appreciated. There are a great many native parasites of native caterpillars which are very similar and in some instances indistinguishable from those of the Glyptapanteles, but none of these have ever been recorded as attacking the gypsy moth.

The one great fear in connection with the introduction of this most important parasite is that it will not find all of the natural conditions necessary for its continued existence in Massachusetts. Its life during the fall and its whereabouts during the winter are equally a mystery; and even the Japanese entomologists, who are the keenest of observers, resident in a country where it is a relatively common insect, are wholly unable to suggest a reasonable solution. It has been recorded upon a variety

[1] The occurrence of the cocoons in the near vicinity of the colony sites immediately following the liberation is most natural, and in perfect harmony with the wide dispersion. The female parasites as soon as they emerge are ready to deposit a small part of the eggs which they will eventually deposit if they live and have opportunity. After the deposition of this part, it is necessary for them to wait an appreciable time before they are ready to deposit any more.

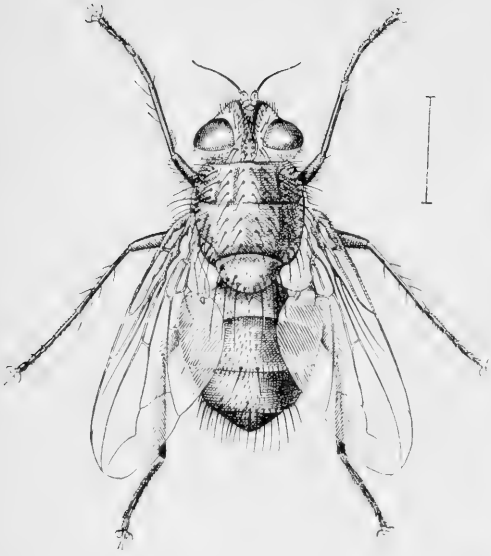


FIG. 10. — *Blepharipa scutellata:* important European parasite of gypsy moth caterpillar, adult, enlarged.

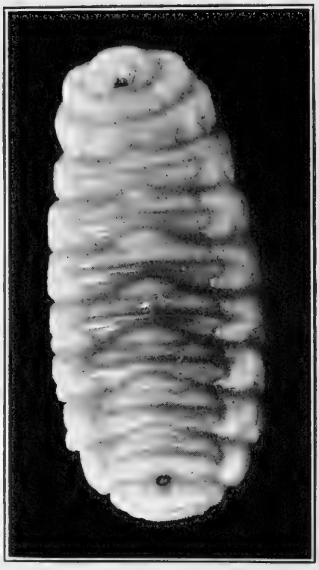


FIG. 11. — Blepharipa: full-grown larva from gypsy moth pupa, enlarged about six times.

FIG. 12. — Blepharipa: puparia, slightly enlarged.

of other caterpillars in Europe, but these records are known to be erroneous in part, and all are likely to be so. As stated just above, there are numerous other species which are easily confused with it, but none of them appear to attack the gypsy moth; and, *vice versa,* absolute proof that the Glyptapanteles of the gypsy ever attacks any other host is at present lacking.

It is one of the most important parasites, perhaps the most important, and fills a gap in the sequence which it will be exceedingly hard to fill should it fail to become established. If it demonstrates its ability to live in America, it is safe to say that the greatest and most-feared of all of the obstacles to success will prove to be nonexistent.

Blepharipa scutellata.

Blepharipa belongs to a different order of insects, the Diptera, which consists of the true flies, while the egg parasites and Glyptapanteles belong to the order Hymenoptera, and are more nearly related to the bees and wasps. The latter are characterized by four membranous wings, while Blepharipa has but two wings, and is the first of the several parasites which will be mentioned which belongs to the family Tachinidæ of order Diptera. The Dipterous parasites of the gypsy moth and of the brown-tail moth are all members of this family, and will frequently be referred to as the Tachinid parasites, in contradistinction to the Hymenopterous parasites.

The Tachinid parasites, as a class, differ markedly in their manner of life from the Hymenopterous, but not all of them to quite the extent of the one under consideration (Fig. 10). It attacks the gypsy moth during several of the caterpillar stages, but instead of depositing its eggs within the body of the host, they are deposited upon leaves of trees infested by the caterpillars. They are exceedingly minute, black and shining, and one fly can lay many thousands. When eaten by a caterpillar big enough not to crush them in the process they hatch almost immediately into tiny maggots, which pierce the walls of the alimentary canal and lodge themselves in the fatty tissue of the caterpillar's body. They grow slowly, and invariably, if parasitism is successful, the caterpillar pupates. When the moth would have been about ready to issue, had the pupa been healthy,

the Blepharipa maggot (Fig. 11) reaches maturity and works its way out of the now empty shell. It then drops to the earth and burrowing its way several inches below the surface, transforms to a puparium (Fig. 12), an oval, dark body, formed of the hardened skin of the larva, and containing the true pupa. This pupa remains unchanged during the winter, and produces the perfect fly in the late spring following.

Blepharipa is a very important parasite of the gypsy moth in Europe, and in western Europe appears to be very much more destructive than does the Glyptapanteles. It is represented in Japan by another very similar species (*Crossocosmia* sp.), the adults of which have not yet been reared at the laboratory.

The difficulties which have stood in the way of the successful introduction of this parasite into America have been different from any that have hindered the work with any other species. Importation of the full-grown caterpillars or freshly formed pupæ of the gypsy moth resulted in 1905 in securing a considerable number, several hundred at least, of the hibernating puparia, but not a single fly issued the following year. The cause was not obvious at the time, but was later determined to be due to the drying up of the pupæ within the puparium. Death did not immediately ensue, but eventually the fly would die when it was nearly ready to issue. A great many different methods of hibernating these puparia have been attempted, and with very variable but uniformly unsatisfactory results. During the winter of 1907–08 the puparia were kept in moist earth, and a 10 per cent. emergence from a total of 5,000 was secured. The year before it was less, hardly equalling 3 per cent., and the year following much less, hardly amounting to 1 per cent. These tremendous losses were unexplained until the summer of 1909, when large numbers of gypsy caterpillars were received in a living condition from Hyeres, France, through the magnificent efforts of M. René Oberthür of Rennes, and as a direct result of Dr. Howard's trip to Europe that year. (Plate II.) They came in better shape, in many respects, than any other similar lot of material ever received, having been shipped in cold storage on fast transatlantic liners.

For the first time since the inception of the work, large numbers of living pupæ containing the immature maggots of

the parasites were received at the laboratory, and it was possible to allow the formation of the puparia under natural conditions in the earth. Each preceding year the maggots had reached their maturity, and formed, or attempted to form, puparia in the boxes in transit. They were often injured, and the puparia were always thoroughly dried when received.

A very large number of the parasites were secured in this manner (25,000, as a conservative estimate), and several thousands of the maggots were allowed to enter the earth in the open in forests infested by the gypsy moth. Examination has demonstrated the fact that these maggots pupated in a perfectly natural manner, and the condition of the pupæ at the present time is far and away more satisfactory than it has ever been before at this season of the year. It is almost impossible to conceive of conditions which will prevent the emergence of these flies in large numbers in the open the coming spring.

The remainder of the maggots were allowed to go into the earth in a variety of containers, principally sunken wire screen cages in the laboratory grounds. They, as well as those in the open, are in the best of condition, and it will be a severe disappointment if a large number of the flies are not reared and colonized, as a result.

The parasite was colonized as adults in small numbers and under satisfactory conditions in the spring of 1907, and in somewhat larger numbers in 1908. No results have been secured to date, nor are immediate results expected from these early colonies. The fly is very strong, and it is to be expected that it will fly for long distances during the considerable period of its activity in the spring. Unlike Glyptapanteles, Schedius, etc., it is not ready to deposit its eggs for something like three weeks after it issues in the spring, and during this time it is likely to traverse considerable distances. It is a source of great regret that it has not been liberated in large numbers much earlier in the course of the work; but it was not until after numerous experiments had been made, through which it was hoped to remedy the obvious defects in methods of importation and handling, and all modifications proven to be useless, that the extraordinary methods of last season were adopted. There is not a single other one amongst the numerous species of

Tachinid parasites, except the Japanese Crossocosmia, which is nearly so difficult to handle.

Multiplication of this parasite in the open, under favorable conditions, which it is believed the present season offers, ought to be exceedingly rapid. As in so many other instances, the year to come is crucial, and will likely demonstrate the ability of this species to become Americanized.

Success with Blepharipa, and its rapid acclimatization in America, is looked for more especially on account of the close correlation which exists between the parasite and host. Like Anastatus, this correlation is perfect, and the parasite is able to continue its existence from year's end to year's end, independent of any other insect. This, in connection with its extraordinary powers of multiplication, make it one of the most promising of the parasites studied at the laboratory, and perhaps the most promising of all.

Compsilura concinnata.

Only a very few of the introduced parasites are equally important as enemies of both the gypsy moth and the brown-tail moth, although a number of them are known to attack both to a varying degree. One of the few which are important enemies of both is Compsilura, a Tachinid fly like Blepharipa, but differing from that species in a great many important particulars. Instead of depositing eggs on the foliage, to be eaten by the caterpillars, the eggs hatch in the body of the parent female, and the minute maggots are thrust beneath the skin of the host after a fashion somewhat comparable to the manner in which Glyptapanteles deposits its eggs in the active caterpillars. Usually only one parasite develops in one host.

The maggots begin to feed at once, and in a very short time (less than two weeks in the summer) are full fed, and have caused the death of the host caterpillar. They then work their way outside of its body, drop to the earth and transform to puparia, from which shortly after the adult flies issue.

Since the parasite has been secured in both brown-tail and gypsy moth parasite importations, the numbers which have been received and liberated have been considerable. The first colonies were planted in 1906, and in each year since, but particu-

larly in 1909, new colonies have been located in various parts of eastern Massachusetts. There is no better method for the recovery of the parasite from the field than the collection of gypsy or brown-tail caterpillars and their confinement in cages, where they can be fed, and where the parasite can be secured in case it is present and emerges. This is a tedious process, involves a large amount of labor, and in the case of the brown-tail caterpillars entails much discomfort in its execution; and attempts to determine the distribution of the parasite in the field have not been as thorough as it is intended that they shall be in 1910. Nevertheless, it was recovered from the field upon several occasions in the course of the summer of 1909, and there seems not to be any question that it is thoroughly established and widely distributed in Massachusetts at the present time. Its rate of increase, if the widespread distribution is taken into account, is wholly satisfactory, and, as indicated by the field collections, is as great as of Calosoma and perhaps as of Monodontomerus. It must be remembered, in this connection, that there is no simple means of determining its distribution, as is the case with both of the other species mentioned; and furthermore, that, although it was liberated in 1906, it was not until so late in the season as to make a generation upon the gypsy or brown-tail caterpillars improbable during that year. It was not until 1907 that it can be considered as having had its first good opportunity for reproduction in America, and the fact that it was found to be generally distributed the third season in the field is indicative of a particularly satisfactory progress.

It is not a very important parasite of either the gypsy or the brown-tail moth in Europe. It has never been received from Japan, and it is not expected that it will become of more than relatively minor importance in either connection here, as compared with Blepharipa and Glyptapanteles. At the same time, it has points in its favor not possessed by any other parasite, notably, its ability to pass one generation upon the brown-tail caterpillars and another immediately after upon those of the gypsy; and it is likely to gain in effectiveness, in this manner, a part of what it loses through its probable inability to complete its seasonal cycle without the assistance of an alternate native host. It is very democratic in its choice of hosts, and

has been reared in the laboratory from a considerable variety of native caterpillars, including such common species as the fall web worm and the Datana caterpillars, which are frequently so abundant upon various trees and shrubs in the fall.

Tachina larvarum and *Tricholyga grandis.*

These two species of Tachinid parasites are exceedingly similar in many respects and are so difficult to separate in their various stages as to have been confused under the name of *Tachina larvarum* during the first three years of the work. On this account, considerable confusion exists concerning the early history of both in America.

Tachina (Fig. 13), like Compsilura, is a parasite of both the brown-tail and the gypsy caterpillars, while Tricholyga is principally confined to the last-mentioned in its host relations. Both deposit large flattened eggs upon the body of the larger caterpillars, and the minute maggots hatching from these eggs burrow into the body of their host, where they grow rapidly. The larva of Tachina usually leaves its host and completes its transformations upon or just beneath the surface of the earth. That of Tricholyga may do this, or it may remain attached to the host and never drop to the ground at all. Both species usually kill the host caterpillars before pupation, but not always.

Several thousands of one or both species were liberated in various localities in 1906 and 1907. Both were colonized in small numbers in 1908, and in very large numbers in 1909. It was not known that either species had established itself until late in the summer of 1909, when Tricholyga was recovered from the field as a parasite of the gypsy moth from the near vicinity of a very small and unsatisfactory colony of the year before. There seems to be every reason to believe that it has succeeded thoroughly in establishing itself, and that it is a mere matter of time until it shall become so common as to be of active assistance in the control of the gypsy moth.

The Tachina, strangely enough, is scarcely distinguishable as an adult, or in any other way than by its behavior as a gypsy moth parasite, from a native American species which has upon rare occasions been reared as a parasite of the gypsy moth. The native species is probably the one which deposits its conspicuous

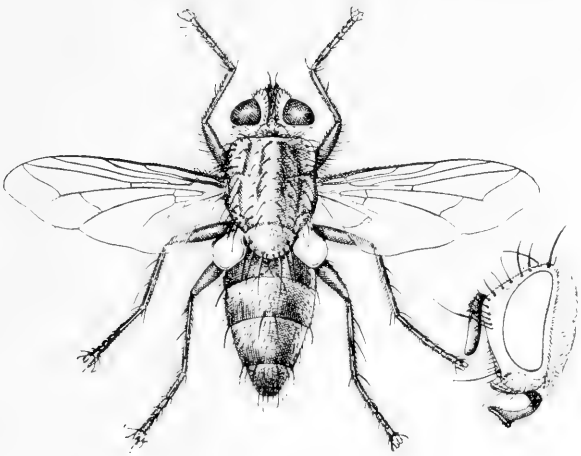


FIG. 13.—*Tachina larvarum:* European parasite of gypsy and brown-tail moth caterpillars, adult, enlarged.

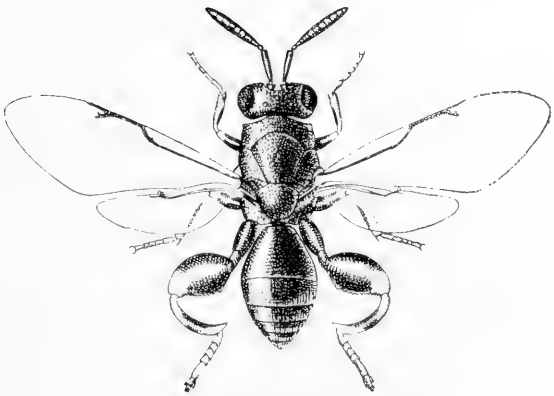


FIG. 14.—*Chalcis flaripes:* European parasite of gypsy moth pupæ, adult, greatly enlarged.

white eggs upon the larger caterpillars of the gypsy moth in certain localities each year so abundantly as periodically to attract attention; but the identity of these eggs cannot be determined, since the maggots which hatch from them rarely go through to maturity. The reasons for this extraordinary state of affairs have not been accurately determined, but in some way the caterpillars of the introduced insect are not fitted to the needs of the maggots of the native parasite.

It has been stated that the native species occasionally completes its growth and transformations upon the gypsy moth, and, since it is impracticable to separate the adults with certainty, there will be no way of following the progress of the imported species in America until it shall become a great deal more common than the native in this connection. It is unquestionably too soon to look for such conditions at the present time, but it is rather confidently expected that within a few years *Tachina larvarum* will become an efficient link in the sequence of parasites which it is hoped to establish.

There is a species of Tachina in Japan, indistinguishable in habit from the European species, and apparently rather more effective. The adults are different, however, and quite easily distinguished from either the American or the European. A small number have been liberated, and it is possible that they will be heard from in the future. It is also expected that a larger number will be imported and liberated the coming season, so that, if the European species for any reason should fail to come up to expectations, the position which it might otherwise occupy will not remain vacant.

Zygobothria gilva and *Carcelia gnava*.

Through the efforts of M. Réné Oberthür of Rennes, very large shipments of gypsy caterpillars and pupæ were received from France in 1909 in much better condition than any considerable shipments ever received before. Largely because of the satisfactory condition of the material on receipt, and partly because the two parasites named above are more common in the Mediterranean region than in northern or central Europe, several thousands of each were imported and colonized under the happy circumstances which accompanied nearly all of the

colonizations in 1909. Both had been received before, and both had been colonized, but in insignificant quantities and under conditions which left much to be desired. It is considered, therefore, that the first satisfactory and possibly the first effective colonization of these parasites was accomplished last year.

Both are Tachinids, and similar in many respects to Tachina, Compsilura, etc., but differ from all others and from each other in many minor particulars in their life and habits. In relative importance, as determined by the frequency of their occurrence abroad, they are about equal in rank, and compare favorably in France with any other Tachinid parasites except Blepharipa.

It is hoped that both will establish themselves in America, but their ability to do so remains to be proven, and it is hardly to be expected that either will be recovered before 1911 or 1912, unless some of the earlier and relatively very unsatisfactory colonizations should have resulted more favorably than is now believed to be the case.

Parasites of the Pupa.

Theronia sp.

There are at least 10 species of large, wasp-like parasites which attack the freshly formed pupæ of the gypsy moth, and the caterpillars just previous to their transformation, and which belong to the genera Pimpla and Theronia. All of them are very general in their host relations, and will attack the pupæ of almost any moth which they encounter under the proper conditions; but none of them, with the exception of the several varieties or species of the genus Theronia, have ever occurred so abundantly in any lots of imported gypsy pupæ as to justify a position among the important parasites of the gypsy moth. As parasites of the brown-tail, the several species of Pimpla are quite effective both in Europe and America; and Theronia is also a brown-tail parasite, but of relatively less importance.

There are three species or varieties of Theronia, inhabiting respectively Europe, Japan and America, and all are very similar in appearance and habits. The American species, *Theronia fulvescens,* appears to have reached its maximum effectiveness

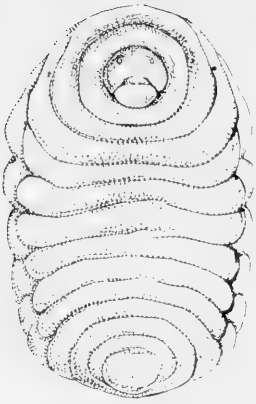


FIG. 15. — Chalcis: full-grown larva from gypsy moth pupa, greatly enlarged.

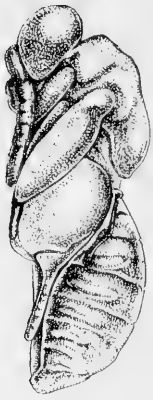


FIG. 16. — Chalcis: pupa from gypsy moth pupa, greatly enlarged.

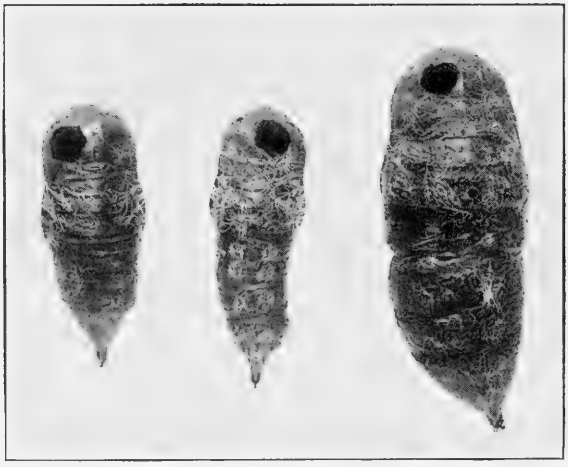


FIG. 17. — Chalcis: gypsy moth pupæ, showing exit hole of the parasite, enlarged.

in America, and without exceeding in this respect the Japanese or the European species in their respective countries. A few of the European *Theronia atalantæ* have been liberated in America, but nothing more is expected of it than of *Theronia fulvescens;* and, as a matter of fact, it will be difficult to determine whether it is established or not, owing to the very close resemblance between the two.

Theronia will help a little in the ultimate control of the gypsy moth in America, but it is not to be expected that it will ever become of greater efficiency than it is at present. It is generally distributed throughout the infested area.

Chalcis flavipes.

One of the most effective parasites of the tussock moth in certain more southern localities is a native species of Chalcis (Fig. 14) which is not very common in any connection in New England. If, as is altogether probable, the gypsy moth extends its southern distribution into the range of Chalcis as a common parasite, it is not at all unlikely that it will be attacked by it.

In southern Europe and in Japan are other species of Chalcis similar to the native species in appearance and habits, and sometimes quite effective parasites of the pupæ of the gypsy moth. They are always solitary, and notwithstanding that there is substance enough in an average gypsy pupa to nourish several individuals, there is no record of more than one ever emerging from one host. The eggs are deposited in the freshly formed pupa, and apparently the individual host is open to attack for a period of only about three days in the course of its life. The larva (Fig. 15) feeds upon as much of the contents of the pupal shell as it desires, and then transforms to a pupa (Fig. 16). The adult emerges later through a large, ragged hole gnawed through the pupal shell. (Fig. 17.)

The European species, *Chalcis flavipes,* was imported in some numbers in 1905, but at that time was supposed to be an enemy of the Tachinids which were primary parasites of the moth, and none were liberated. In 1906 and 1907 none were received, and no opportunity arose to investigate the relations existing between the moth and the parasite. It was not known that it was so closely confined in its geographical distribution at that

time, and since no gypsy moth pupæ were received in good condition from any of the Italian or French collectors, its importance was not recognized.

In 1908, for the first time since 1905, a quantity of gypsy moth pupæ was received from Italy, through the courtesy of Professor Leonardi of the School of Agriculture, Portici, and from them quite large numbers of the parasite were reared. At first, with the recorded secondary parasitism of the species in mind, considerable care was exercised to prevent the escape of any of the specimens until their true relation to the gypsy moth should be established. At last, after a rather tedious series of microscopic studies, supplemented by dissections of the parasitized pupæ, it was definitely demonstrated that the Chalcis which issued from the Tachinid puparia were different from those which came from pupa direct; in other words, there were several species of the genus Chalcis, closely resembling each other in their appearance, but differing entirely in their habits. One of them was, beyond further dispute, a primary parasite of the gypsy moth, and was immediately liberated in the field, while the others were destroyed as fast as secured.

In 1909 a few more were received in importations of gypsy pupæ from Italy and France, and another small colony was established. It is known definitely that reproduction in the field followed immediately after, but there is insufficient assurance that the species is acclimatized in America, since it has not been recovered a full year after its colonization. If it disperses as rapidly as do most of the parasites, it will be some years before it is again recovered as the result of the last summer's colonization. During this period it is hoped that additional importations will make it possible to establish larger and stronger colonies of what, if it can exist here, is very likely to become a parasite of some importance.

In both 1908 and 1909 *Chalcis flavipes* was carried through all of its transformations in gypsy moth pupæ in the laboratory; and, but for the fact that a supply of host pupæ cannot be provided except during a very limited season each year, it would be practicable to institute propagation work similar to that which has been so successful with Schedius and Calosoma. Only about one month is required for the complete life cycle from

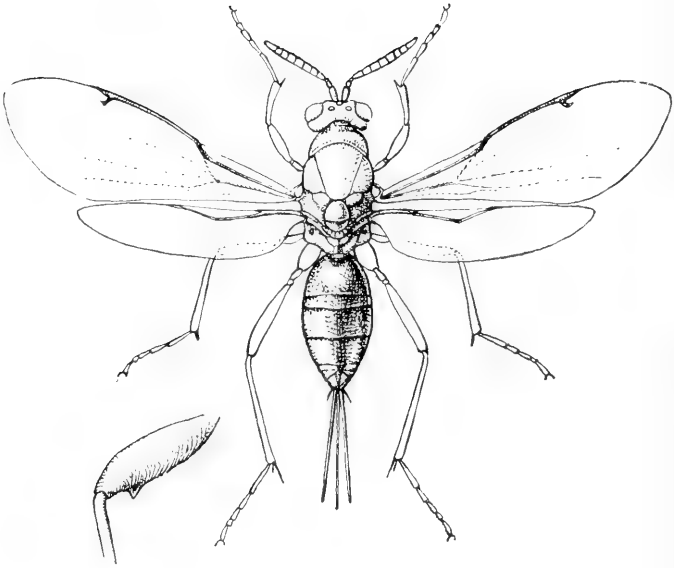


FIG. 18. — *Monodontomerus aereus:* European parasite of gypsy and brown-tail moth pupæ, adult female, greatly enlarged.

egg to adult. It is very probable that the adults live for a long time, like those of Monodontomerus, and they may hibernate.

Monodontomerus aereus.

The females (Fig. 18) deposit their eggs (Fig. 19) in the freshly formed pupæ of the gypsy moth and of the brown-tail moth, several in each individual host. The larvæ (Fig. 20) feed and subsequently undergo all of their transformations within the pupal shell, of which they usually consume the entire contents. (Fig. 21.) A little later than the time when the moth would have issued, had the parasitized pupa remained healthy, the Monodontomerus adults escape through a small hole in the dried pupal shell. (Fig. 22.) From 5 or 6 to 15 or 20 come from each. The males die soon after, but the females live all winter, and are not able to deposit eggs for another generation until the summer following. When cold weather approaches they seek the shelter afforded by the hibernating webs of the brown-tail caterpillars, and remain well protected in the silken chambers during the winter. They come forth in the spring as soon as the weather becomes warm enough to stir them into activity, and in the course of the period intervening between their resumption of activity and the pupation of the brown-tail and gypsy, they develop their eggs and are ready for the attack.

A considerable number of the adults of this parasite, all, without exception, fertilized females, issued from the large number of brown-tail hibernating nests which were imported from various European countries during the winter of 1905–06. A part were given their freedom in the spring, but as it was soon found that the species were not in any way an enemy of the hibernating brown-tail caterpillars, and as their parasitism of the pupæ of the gypsy moth and brown-tail moth was not indicated at that time, their liberation was discontinued. In 1906 and 1907 small numbers were reared from imported cocoon masses of brown-tail, but under conditions which told nothing concerning their host relations. Upon several occasions small numbers have been reared from the puparia of Tachinid parasites of the gypsy moth, and it was feared that the parasite might prove to be habitually secondary, instead of primary.

Like Chalcis, Monodontomerus is more common in southern

Europe, and the small quantities of gypsy and brown-tail pupæ which were received in 1906 and 1907 from those countries where it was most abundant made any attempts to investigate its life and habits difficult of execution. The females would never evince any interest in gypsy or brown-tail pupæ in the laboratory, and all of the many reproduction experiments which were made failed utterly. This was subsequently found to be due to the fact that their eggs were undeveloped, and it was not until a careful series of microscopic dissections were made that this insuperable obstacle to success was discovered.

In 1908 the same importation of gypsy moth pupæ from Italy which served to establish the host relations of Chalcis served also to establish the primary character of the parasitism by Monodontomerus. It was reared from the gypsy moth pupæ direct, and in such numbers as to indicate that it was a parasite of considerable importance; and great regret was felt that it had not been liberated in larger numbers upon the first opportunity. It was hardly considered probable at that time that the small number liberated during the early spring of 1906 would succeed in establishing themselves.

In the winter of 1908–09, large numbers of the hibernating nests of brown-tail were collected from various localities, as they had been each winter since the beginning of the work, and from these nests issued a very few hibernating females of Monodontomerus, exactly as they had previously issued from nests similarly collected in Europe. The circumstance was as unexpected as it was gratifying, and indicated that the parasite had multiplied rapidly in the field, because similar collections of even larger quantities of brown-tail nests had not produced the parasite the year before. Steps were immediately taken to determine the distribution of the parasite, and the surprise was greater when it was discovered to be sparingly but generally distributed over an area of approximately 500 square miles, extending in nearly every direction, but farthest to the west, from the original point of liberation.

In the summer of 1909, when the proper season had arrived, it was recovered for the first time as a parasite of the gypsy moth in the field. Although it was not very common, it was found to be generally distributed, exactly as indicated by the collections

FIG. 19. — Monodontomerus: egg, greatly enlarged.

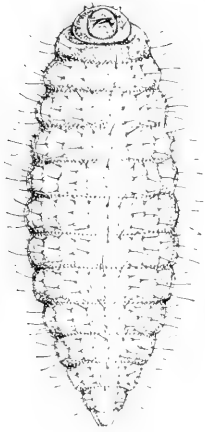


FIG. 20. — Monodontomerus: larva from gypsy moth pupa, greatly enlarged.

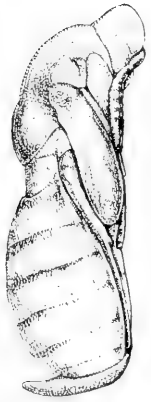


FIG. 21. — Monodontomerus: pupa from gypsy moth pupa, greatly enlarged.

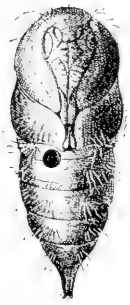


FIG. 22. — Monodontomerus: gypsy moth pupa, showing exit hole left by parasite, greatly enlarged.

from brown-tail nests the winter before. The percentage of the gypsy pupæ destroyed was negligible; but the fact remained that the parasite was on the increase, since exactly the same methods employed in previous years had produced no such results.

Great curiosity was felt as to the probable character of the results of winter work in the recovery of the hibernating females in the winter nests of brown-tails in the fall of 1909, as this would provide the first opportunity to determine the rate of annual increase and of dispersion. The work was begun as soon as practicable, and, while the results are not yet complete, they are more favorable than was at any time anticipated. In brief, the insect is now known to be distributed over an area of approximately 3,000 square miles. Every portion of the Commonwealth north and east of Boston to the New Hampshire line, and as far west and southwest as Leominster, Shirley and Dover, is included in this territory. It is certain to be in New Hampshire, but to date none have been received from that State, and the western limits of its distribution have not been determined.

Everywhere in the area which was not included in its known distribution last year it is about as common as it was in any place the winter before. Within the limits of the territory in which it was known to occur a year ago it has increased at least twenty-five-fold during the year. At this rate, if unchecked, it would be abundant enough to destroy *all* of the gypsy and brown-tail pupæ in three years more. Since this, for various reasons, is highly improbable, it is likely that it will reach its maximum effectiveness within the centrally infested areas by that time. Judging from the best which it is known to do abroad, this will be the destruction of something like one-fourth of the gypsy and brown-tail pupæ. It is not abroad, and cannot be expected to become in America a parasite of as great importance as Glyptapanteles or Blepharipa, provided these species become as thoroughly acclimatized; but it promises to become a very valuable parasite, occupying, as it does, a position in the sequence of parasites which would otherwise be vacant except for the ineffective Theronia or the less certainly efficient Chalcis.

PROGRESS OF THE PARASITES IN MASSACHUSETTS.

Before it is possible accurately to predict the progress of an insect in a new country, it is necessary to know, first, the average rate of increase under the new conditions; and, second, the average rate of dispersion. Neither may be determined otherwise than by actual observation in the field. In the countries to which the insect in question is native, the rate of increase is balanced more or less perfectly, and, although it always fluctuates somewhat in relative abundance from one year to another, there is no permanent gain or loss. The dispersion of an insect in a country where it is native and generally distributed is impossible of determination; the progeny of any given parent or of the parents within a given area are at once confused with the progeny of parents in any part of the surrounding country into which they may chance to spread.

The introduction of an insect into a new country is usually followed by a steady increase, which is sustained until it has established a balance with the native insects; or by a steady decrease, which results in its final extinction.

There are a few instances on record in which the progress of an introduced insect has followed neither path. The Chinese lady-bird (*Chilchorus similis*) was introduced into Georgia in 1902 as an enemy of the San José scale, and for one year increased at a very rapid rate, and spread over a considerable territory from the point where it was liberated. It passed the first winter successfully, and for a time bade fair to become so numerous as to be of valuable assistance in the fight against this scale; but in 1904 its numbers showed a decided decrease, and at the present time it appears not to be at all common. The causes for this are very obscure, and no satisfactory explanation has ever been advanced.

The history of the Oriental moth in Boston, where a few years ago it appeared to have become firmly established, is another case in point. At the present time it is far from common, and it is very possible that eventually it will become extinct.

It will never be known how many insects have been introduced into America from abroad, but the number is undoubtedly far

in excess of those which have become temporarily or permanently abundant enough to attract attention.

It has never been expected that all of the parasites and predatory enemies of the gypsy and brown-tail moths which have been introduced into Massachusetts would continue to exist here. It has always been expected that certain of them would do so, and the only cause for uneasiness as to the ultimate success of the work has been the fear that not enough different kinds of parasites could be secured for colonization, or, if colonized, that not enough to form a natural and effective parasitic sequence would be able to continue to exist. At the present time there is no parasite of the gypsy moth, and only one or more of the brown-tail, of which it can be said that the progress is unsatisfactory. Just what the progress is, or whether there is any actual progress, is not known in every case; but, as will be shown, it may be very satisfactory, and at the same time inconspicuous.

In the beginning it was expected that increase, if it followed colonization, would be rapid; but it was not thought that many of the several species would be likely to fly very far from the point of liberation until they had increased for several generations. Had these expectations been fulfilled, practical results would have been apparent, locally, within three or four years.

So far as it is possible now to state, the rate of multiplication has generally been gratifyingly rapid; but it has been accompanied by a rate of dispersion so much greater than was expected as to materially change the aspect of the situation. It is now evident that, if success follows the work of parasite introduction, the parasites will become practically effective over a considerable portion of the infested area, and possibly throughout its whole extent, at about the same time.

In order better to illustrate this point, a theoretical example may be taken of an insect introduced into a new country, where it increases at the rate of twenty-five-fold annually, and spreads from the point of liberation at the rate of about 10 miles annually. It is supposed that 1,000 individuals are liberated in a territory where they can be spread in every direction, and where their increase will be unhampered for a period of six years.

Lest any one should think that the figures and diagrams as given are fanciful, and the result of pure speculation, it is well to state in the beginning that they represent, as accurately as the available information will permit, the progress of Monodontomerus in the field. The territory covered is not quite as extensive as indicated by the first diagram, owing to the fact that a large part of it is, or would be, open sea; but the recovery of the parasite from the field indicates that it has spread at a rate of approximately 10 miles annually to the west and north, and that its increase, which was about twenty-five-fold during the summer of 1909, has been maintained at that rate since its liberation. It is not known exactly how many of the parasites were liberated originally, the notes which were made at that time apparently having been lost. Tentatively, the figures are set at 1,000.

The rate of dispersion, provided it was dependent upon the activities of the insect, and not upon chance or accidental agencies, would be about as rapid during the first year from a colony of 1,000 as though it were very abundant. The territory covered by the insect during the six years would therefore be represented by a series of six concentric circles, the smallest of which would have a radius of 10 miles, and each of the others of multiples of 10 up to 60. The area given in acres, and for convenience sake in round numbers, over which the insect would range each year from the first to the sixth, respectively, would be as indicated in Diagram I.

Increase numerically, at the rate of twenty-five-fold annually, would be at a very much more rapid rate, and is indicated by the several squares in Diagram II. It would be impossible to illustrate this increase diagrammatically for the entire six years without the use of a large chart, because the square which would indicate the number of the insects which would result from the sixth year's increase would have sides between 3 and 4 feet long. The figures for six years would be: —

1906,	1,000
1907,	25,000
1908,	625,000
1909,	15,625,000
1910,	390,625,000
1911,	9,725,625,000

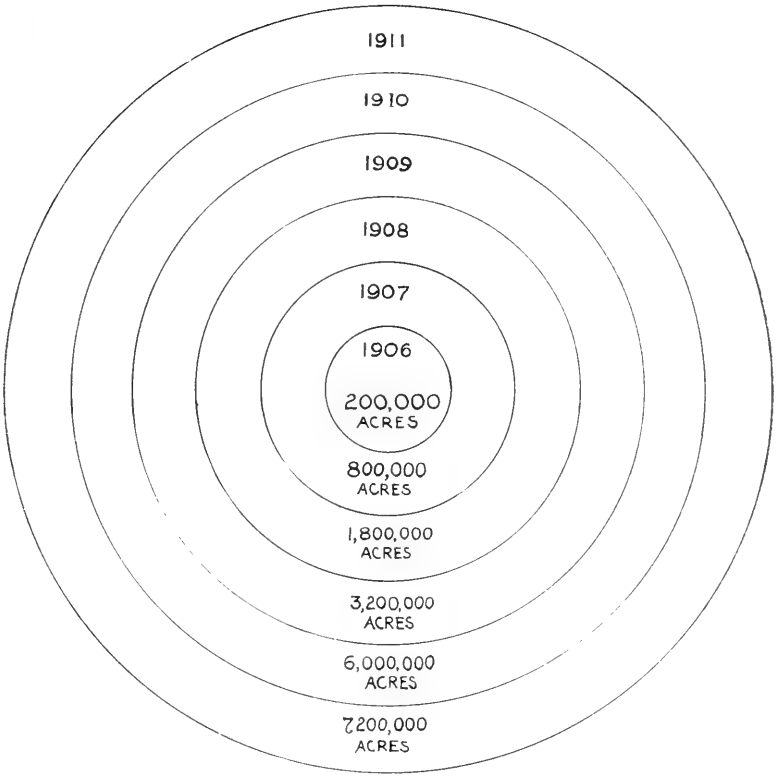


DIAGRAM I. — Illustrating the dispersion of an introduced insect for six years, at the rate of approximately ten miles per year.

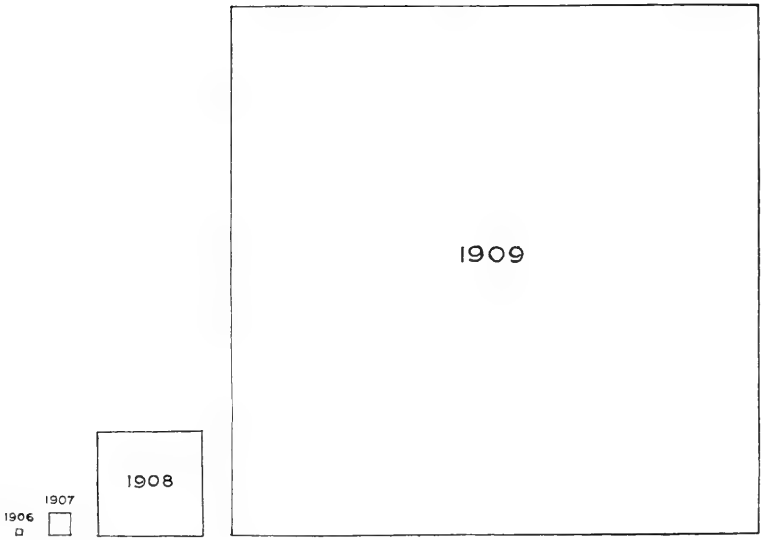
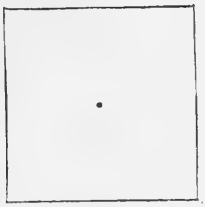
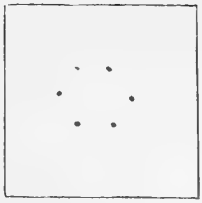


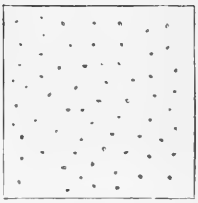
DIAGRAM II. — Illustrating the numerical increase of an introduced insect for four years, at the rate of twenty-five-fold each year.



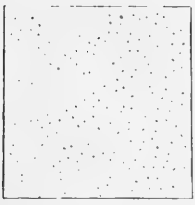
1906.
1 individual to 200 acres.



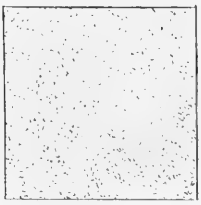
1907.
5 individuals to 200 acres.



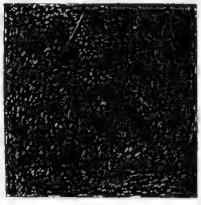
1908.
69 individuals to 200 acres.



1909.
976 individuals to 200 acres.



1910.
15,625 individuals to 200 acres.



1911.
270,156 individuals to 200 acres.

DIAGRAM III. — Illustrating the increase in average abundance of an introduced insect which disperses as indicated by Diagram I. and increases at the rate indicated by Diagram II.

Increase in the average abundance of the insect from year to year over the area included in its range would be comparatively slow at first, but would later become much more rapid, on account of the rate of increase being so much greater than that of dispersion. An attempt has been made to illustrate it in Diagram III., in which each square represents an area of 200 acres. The number of the insects (Monodontomerus in this instance) which are to be found within a territory of this extent is indicated by the black dots. It becomes impossible to crowd a sufficiently large number into the limited space available to indicate accurately the proportionate abundance which will result in 1910 and 1911, if the rate of increase continues without diminution.

The parasites are generally very inconspicuous, and when not common are difficult to find. Monodontomerus, as has been stated, is particularly easy to find, owing to its hibernating habits, and it is partly on this account that so much is known of its progress. The only methods which may be employed for the recovery of the most of them is the collection of a quantity of the caterpillars or pupæ of the gypsy moth, which are confined in the proper form of cage in the laboratory until the parasites issue from the affected individuals after destroying them. To collect all of the gypsy caterpillars or pupæ over a territory as large as 1 acre is out of the question when the insect is abundant. It is therefore impracticable to follow systematically the progress of an insect which would be so uncommon as to be represented by only a single individual in an area of this extent. It is small wonder that no trace of certain of the parasites which have been liberated has been found during the first few years following.

It was not until the summer of 1909, the fourth after its establishment, that Monodontomerus was first recovered as a parasite of the gypsy moth in the field; and if a parasite can increase at such a rate and remain unnoticed for three years, there is good foundation for hoping that other species may be doing as well.

The Calosoma beetles, which were also liberated for the first time in 1906, in time to attack the gypsy moth caterpillars that year, have ever since increased at a less rapid but at the same time a very satisfactory rate. Their rate of dispersion is also much less, and probably does not exceed a mile or two per year.

It will be several years before they will reach the abundance at present held by Monodontomerus.

These two insects, Monodontomerus and Calosoma,[1] were the only enemies of the gypsy moth which were liberated in 1906 in time to attack the gypsy caterpillars that year. A number of other parasites were given their freedom during the late summer or fall, after the caterpillar season was nearly or quite over, and the first opportunity which they had to attack the gypsy or the brown-tail caterpillars was in the year following. Of these parasites, one, Compsilura, has been recovered in the past summer in numbers in every way as large as could be expected, if its rate of dispersion is as rapid as that of Monodontomerus. A greater rapidity of dispersion and multiplication, sustained over a period of years, has not been expected of any of the introduced insects.

WHEN WILL THE PARASITES BECOME EFFECTIVE?

This question, which has been asked so frequently, has always been avoided, especially since it became apparent that the dispersion of the parasites was going on at an unexpectedly rapid rate, making their recovery difficult except in the immediate vicinity of the colony and immediately after colonization. It was obviously impossible, under such circumstances, to determine what their actual progress was; and the only results which were apparent to those in charge of the work were so technical in their nature as to be of little significance to any one not thoroughly familiar with entomology.

During the past few months considerable data have been accumulated, uniformly satisfactory in character, which bears upon the rate of dispersion or of multiplication of certain of the parasites. It is very insufficient, but if it is reliable, and if the progress of the first among the parasites and predators to be liberated may be taken as a criterion of what is to be expected of the others, it is possible to make a fair estimate of the length of time required for the parasites to become sufficiently abundant and so generally distributed as to bring about an effective natural control of the gypsy moth. The different species differ

[1] *Calosoma inquisitor*, another predaceous beetle, was also liberated in 1906, but in rather small and unsatisfactory numbers. It has not been recovered.

in so many particulars, however, as to make such an estimate at the present time largely speculative.

In Table 4 are listed all of the parasites of the gypsy moth which have been liberated in America under conditions in every way satisfactory. The dates when the first satisfactory colony of each was established will be found in the second column. When, as so frequently happened, the parasite was secured too late in the season to make its attack upon the caterpillars possible until another year, the circumstance is indicated in the third column. The fourth column indicates when the parasite was first recovered from the immediate vicinity, and the fifth when it was found to be generally distributed. On the supposition that the progress of the parasites later liberated will be comparable with that of the earlier, the dates when each of the species listed can be expected to become effective in their respective rôles of egg, caterpillar or pupa parasites, are indicated in the last column.

TABLE 4. — *Showing Date of Liberation and Subsequent Progress of the Parasites of the Gypsy Moth in Massachusetts.*

PARASITES.	First liberated under Satisfactory Conditions.	First Opportunity to reproduce as a Parasite or Enemy of the Gypsy Moth.	First recovered from Immediate Vicinity of Colony.	First recovered at a Distance from Colony Site.	Will probably become Effective.
Theronia fulvescens,[1] . .	–	–	–	–	–
Monodontomerus aereus, . .	1906	1906	–[2]	1909	1911
Calosoma sycophanta, . .	1906	1906	1907	1909	1911
Compsilura concinnata, . .	1906	1907	1907	1909	1912
Tachina larvarum, . . .	1906	1907	–[3]	–[3]	1912
Tricholyga grandis,[4] . . .	1906 ?	1907 ?	1909 ?	1909 ?	1912 ?
Glyptapanteles fulvipes, . .	1908	1909	1909	–	1914
Anastatus bifasciatus, . .	1909	1909	1909	–	–?
Schedius kuvanæ, . . .	1909	1909	1909	–	1912
Chalcis flavipes, ...	1909	1909	1909	–	1915
Blepharipa scutellata, . .	1909	1910	–	–	1916
Zygobothria gilva, . . .	1909	1910	–	–	1916
Carcelia gnava, ...	1909	1910	–	–	1916

[1] A native parasite, of slight relative importance.
[2] First recovered at a distance from colony.
[3] Adults indistinguishable from a native species, which is rarely parasitic on the gypsy moth.
[4] It is not known positively when Tricholyga was first liberated, owing to its very close resemblance, in appearance of adult, to Tachina. The recovery from the field in 1909 may have been the result of colonization in 1908, or equally well of that of earlier years.

Earlier in this paper an attempt was made to point out the necessity of establishing a sufficient number of parasites to form a natural sequence, which would attack each stage of the moth, from egg to pupa. Every parasite necessary to make an effective sequence is represented in the list given, but there are several, including at least one of considerable importance (*Blepharipa scutellata*), which may not become effective before 1916. Since the chain is no stronger than its weakest link, the sequence of parasites will not become fully effective until each necessary component of the sequence has reached the necessary abundance. It will be 1916 before the complete control of the gypsy moth in New England can reasonably be expected, and, unless the writer is mistaken, this control, when it is effected, will be general over all of the infested area.

THE WORK IN 1910.

The year 1910 will be crucial in one respect, since it will give ample opportunity to prove or disprove a number of the premises which have been used as a basis for the above calculation. It ought to be possible to follow the progress of several parasites very exactly, and their progress must be proportionate to the distance which they must travel if they are to become effective in their respective rôles by the time set. Should the actual developments of this season fall short of what is considered to be a necessary amount of progress, the disappointment of those in charge of the work will be very great.

It is hoped that Monodontomerus will increase at about the same rate which has prevailed in the past, but a slight falling off is rather expected. In like manner increase in the numbers of and in the territory covered by Calosoma ought to be commensurate with the progress of this species during the past year. Compsilura ought to be recovered with ease, and it should be possible to determine more accurately its rate of increase and of dispersion. Tachina ought to be recovered for the first time, and Tricholyga may or may not show decided increase, owing to the doubt which exists concerning its early history in America. It is hardly expected that Glyptapanteles will be found at all. If it were, the circumstance would be more encouraging than anything which has happened: first, because it would allay the

doubts which have been felt as to its ability to exist here; and second, because it would indicate an increase beyond what could be reasonably expected. The egg parasites, Anastatus and Schedius, and the Tachinid Blepharipa, must demonstrate their ability to survive the New England winters. It is hardly to be expected that Carcelia, Zygobothria and Chalcis will be recovered. Should any or all of them be found, it would be considered as particularly encouraging.

PARASITES OF THE BROWN-TAIL MOTH.

The brown-tail moth is generally and with justice considered to be the less injurious of the two imported pests, and largely on this account the major part of the space in this bulletin is devoted to the consideration of the gypsy moth and its parasites. It must not be concluded from this, however, that the parasites of the brown-tail moth have been treated with less consideration in the laboratory. They have received their full share of attention, and work upon them, which naturally begins in the winter, at a time when very little can be done on the parasites of the gypsy moth, is largely completed by the end of June, before the larger and more important importations of gypsy moth material are received.

The brown-tail is generally more common and more frequently injurious than the gypsy moth in Europe, and appears to be less completely controlled by its parasites. It is attacked by a greater variety, but more of the species are of distinctly minor importance.

There are at least six parasites native to America which attack the brown-tail moth as freely as the native Theronia attacks the gypsy moth. One of these, Diglochis, is apparently the same as the European *Diglochis omnivorus*. All but one of the remainder are very similar in habit to European species, as may be seen by reference to Table 5.

All of the European parasites known to be of importance abroad have been imported and liberated in some numbers; but in a few instances we have not been able to secure a sufficiently large number to establish strong colonies. Several of the European species, on account of their very close resemblance to American forms which attack the brown-tail in this country,

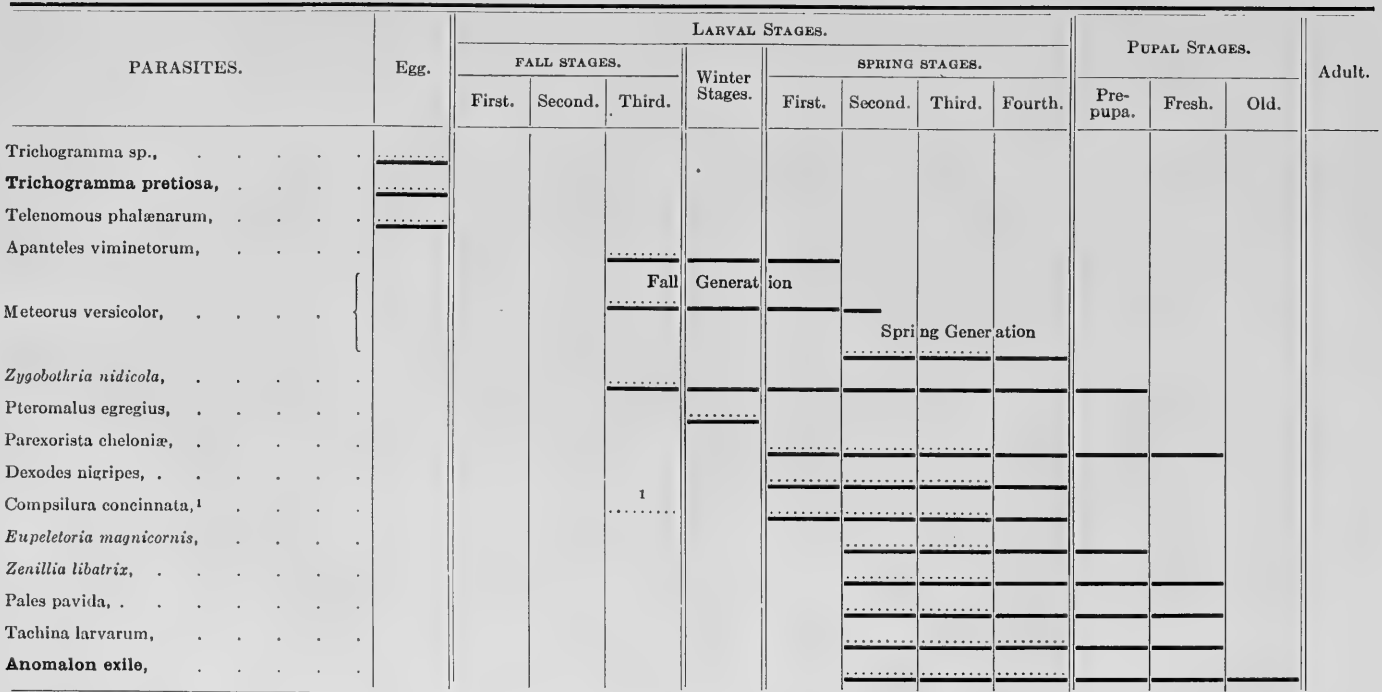
cannot be considered as of much promise; and two (Trichogramma and Pteromalus) have been given every opportunity to prove their worth, but have not responded at all satisfactorily.

There are, however, ten or twelve European parasites different from any known to attack the brown-tail in America, and which include several of great promise, which will be of material assistance in reducing the present prevailing abundance of their host, if they prove adaptable to American conditions.

In Table 5 are listed all of the known parasites of the brown-tail moth which play any considerable part in effecting its control. The names of the native American species are in black-faced type; those of European species which have been imported in satisfactory numbers and colonized under favorable conditions are in Roman type; while those of the European species which have not yet been received under satisfactory conditions are italicized.

Nearly all of the introduced species have been recovered from the field, but not all of them are known to be firmly established. Three of them, Monodontomerus, Tachina and Compsilura, are promising parasites of the gypsy moth also.

TABLE 5. — *Brown-tail Moth. — Sequence of Parasites.*



[1] Attacks young caterpillars before hibernation, but larvæ apparently fail to mature.

TABLE 5. — *Brown-tail Moth.* — *Sequence of Parasites* — Concluded.

PARASITES.	Egg.	LARVAL STAGES.								PUPAL STAGES.			Adult.
		FALL STAGES.			Winter Stages.	SPRING STAGES.							
		First.	Second.	Third.		First.	Second.	Third.	Fourth.	Pre-pupa.	Fresh.	Old.	
Pimpla pedalis,													
Pimpla conquisitor,													
Pimpla instigator,													
Pimpla examinator,													
Theronia fulvescens,													
Theronia atalantæ,													
Monodontomerus aereus,[1]					1								
Diglochis omnivorus,													

[1] Adult females hibernate in winter nests.