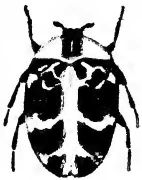

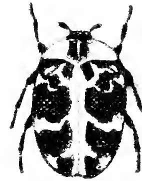

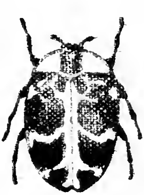

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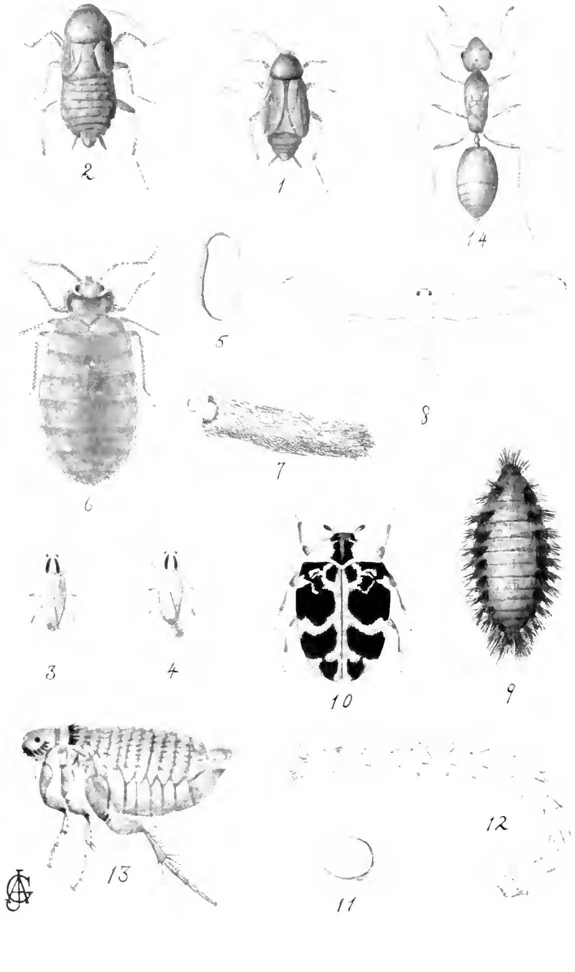
# OUR INSECT FRIENDS AND ENEMIES



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1. The oriental roach or "black beetle": male.
2. The oriental roach or "black beetle": female.
3. The German roach or "croton bug": male.
4. The German roach or "croton bug": female, with egg case.
5. Egg of bed-bug.
6. Bed-bug.
7. Caterpillar of a "clothes-moth" in its case.
8. One of the common "clothes-moths."
9. The "buffalo moth" or "bug."
10. The parent beetle of the "buffalo moth."
11. Egg of a flea.
12. A flea larva.
13. The common dog flea.
14. The little red house-ant.

All of the figures are very much enlarged and most of them were re-drawn from the Bulletins and Reports of the Division of Entomology, U. S. Department of Agriculture.

# OUR INSECT FRIENDS AND ENEMIES

THE RELATION OF INSECTS TO MAN, TO OTHER ANIMALS, TO ONE ANOTHER, AND TO PLANTS

WITH A CHAPTER ON

## THE WAR AGAINST INSECTS

By

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# FOREWORD

NOTHING in this world of ours exists to, for or by itself alone. Every living creature depends upon some other form of life, or upon inorganic matter and is, in turn, the dependence of others that find it useful or essential for continued existence. And as inorganic matter is, after all, the base of organic matter as we know it, plus the addition that makes it organic and whose nature we do not yet know, so in due course all organised forms again return to their lifeless constituents.

Every living thing, then, has relations to many other living things and some of these relations, so far as insects are concerned, it is my object to present. I need hardly disclaim any attempt at completeness; but so far as the presentation goes it claims accuracy. A large proportion of the facts have been personally observed or verified, others are common knowledge and all are based upon the observations or records of scientific investigators.

Some of these relations of insects to the welfare of man have been but recently worked out and are imperfectly known; yet enough has come to the general information to arouse a decided interest in these long despised creatures. Their presence or absence from our midst may make all the difference between sickness and health, irritation and comfort, poverty or wealth, or, on the other hand, wealth and poverty. They make some regions uninhabitable that would otherwise be attractive as sites for homes and, altogether, their influence upon humanity, directly and indirectly, is vastly greater than is generally realized.

# ACKNOWLEDGMENTS

Of the figures illustrating this work, the following were drawn for me by Mr. John A. Grossbeck, my assistant, from originals or modified from published sources: 1, 4, 5, 6, 7, 8, 10, 11, 13, 18, 19, 20, 22, 24, 34, 41, 61, 64, 65, 66, 67, 68, 70, 71, 80, 81, 87, 89, 92, 93, 94, 95, 96, 104, 107.

From the publications of the Entomological Division of the U. S. Department of Agriculture the following were obtained, either as electrotypes or as copies from the prints: 9, 49, 63, 77, 91, 98, 100, 101, 103, 110, 112, 113.

From the New Jersey Agricultural College Experiment Station I obtained blocks for figures 48 and 99.

The other blocks are by courtesy of the J. B. Lippincott Company from my "Economic Entomology," where their original source is stated; but a number of them have been somewhat reduced in size.

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# OUR INSECT FRIENDS AND ENEMIES

## CHAPTER I

### THEIR RELATION TO THE ANIMAL KINGDOM

If we examine any insect, large or small, in any save the egg stage, we note at once that it has its skeleton on the outside of the body. Not much of a skeleton in some cases, *e.g.*, a caterpillar, a slug or a maggot; a very resistant and rigid shell or body wall in others, as in some beetles which may be run over by a heavy wagon wheel without being any the worse, or may pass unchanged through the digestive system of a toad. In any event it serves for the attachment of the muscles on the inside, and they are thus protected, instead of sheltering and protecting an inside bony framework as in man and other vertebrate animals.

It will be further seen, especially in the simpler forms, that the body is made up of successive rings or joints, more or less similar in the primitive types, often very unlike in the higher orders, and that the legs also are made up of a number of parts or segments. These characters place the insects with that great section of the animal kingdom known as *Articulata*, which includes everything from an earthworm to a lobster, and more narrowly restricts them to the *Arthropods*, which have jointed legs, and thus exclude the worms; but still leaves the lobster as a relative.

Matters now become a little more difficult; but if we continue our examinations by comparing a lobster, a spider and a beetle, we find that the latter has a distinct head, separate from the rest of the body, while in the others the head and middle section of the body form a single mass known as a "cephalothorax." Our beetle also will be found to be breathing from the sides of the body through a series of ringed tubes known as *tracheæ* and this makes it a *Tracheate*—an honor that it shares with centipedes or myriapods. Finally, if we persist in our policy of exclusion, we leave as true insects only those forms that have no more than three pairs of jointed legs, attached to the thorax or middle region of the body, the body itself made up of no more than thirteen obvious rings or segments, grouped into three regions, the head, thorax, and abdomen, containing respectively one, three and nine segments.

We are now ready to define an insect as an articulate, arthropod, tracheate hexapod; but it will be equally correct and much easier to say that it is a ringed animal, with six jointed legs, breathing by means of air tubes or tracheæ; this definition applying more particularly to the adult stage, and only to the adult stage of many of those having a complete metamorphosis.

This method of breathing, by the bye, carries with it a modification of the circulating system. The air being carried in tubes to all parts of the body, there is no need for lungs nor for any system of veins or arteries. The blood simply flows about in the interstices of the body cavity, kept in motion by a tube-like heart, divided into chambers, which lies just under the back or dorsal surface, and oxygen is taken up from the tracheæ anywhere in its course, while the products of digestion are taken up from the specialized cells about the digestive system. And, after all, the process of maintaining life

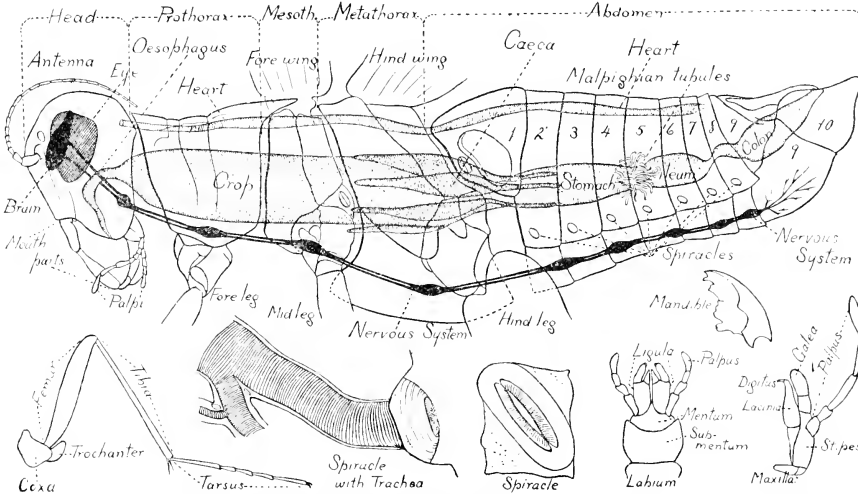


FIG. 1.—An insect and its structure in outline, showing the digestive system, the heart and nerve cord in place. The figures are diagrammatic and the Malpighian tubes are much reduced.

and activity is much the same among insects as it is in the higher animals, although the method is somewhat different. The blood is equally the agent for transporting nutritious material to whatever point it may be needed, and the oxygen to burn out waste products is as essential.

Under the microscope, insect muscle is not so very different from that of man: it has similar transverse striations, and contracts and extends in a similar manner, but, nevertheless, there is no chance of confusing insect with vertebrate muscle. This muscular system is under the control of a nervous system which is very highly developed in detail, but consists essentially of a double cord extending from one end of the body to the other, lying just above the under or ventral surface and furnished with a series of enlargements or ganglia, of which that lying in the head and termed the brain is the largest, although it exercises no such dominant influence as does that organ in the higher vertebrates.

There is quite a difference, of course, among insects, in the amount of specialization in this nervous system. In some and especially in larval forms all the ganglia are similar in size and appearance, and there is one for every segment; in others the tendency to centralization is marked, all the thoracic ganglia being united into one, while in the abdomen two or three of the posterior ganglia join in the control of the reproductive system and the various accessory parts connected with it. The thoracic centre controls the organs of locomotion and a paralysis that is practical death results immediately when this ganglion is cut, whereas we can cut off the head and abdomen, of a house-fly for instance, without interfering with its power to use legs or wings. This fact was known to the digger wasps long before the entomologist knew it, for when such a digger wishes to quiet its prey before carting it home, the sting is aimed at this very ganglion with instantaneous results.

As to senses, the insects have all those of other animals and perhaps more, too; but developed in an altogether different way and to a very diverse extent. Insects see and have the most complicated kinds of eyes known, as well as almost the simplest in existence. Some species are sensitive to rays of light which man cannot see at all and some species certainly seem to see better at night than during the day. But, on the other hand, it is doubtful whether they see at all distinctly or can recognize form and color when not directly connected with their life-needs. So they can hear; some of them very acutely, and ears are by no means confined to the head: they may be on the feet, the body, the abdomen or on the antennæ, and it is believed that they hear sounds so high in pitch that they are beyond the reach of our senses. Nevertheless it is almost equally certain that they are probably incapable of discriminating between sounds, and of really recognizing any but those connected with the sexual calls of their mates or perhaps the noises made by their prey and possibly their enemies. Insects certainly have the sense of taste and some of the most elaborate taste organs are found in species feeding on the vilest excrementitious material. Perhaps the less we say on this point the better, unless it is to suggest that there are gustatory possibilities that man is utterly incapable of appreciating. Insects smell, and this sense is most acutely developed. The male seeks and finds the female almost entirely by this sense even when she is carefully and intentionally hidden from sight, and both sexes find their food by this sense more often than by sight: and that is particularly true of those forms that feed on fermenting or decaying matter. Insects feel, no doubt, and the tactile sense is popularly and probably with justice located chiefly in the antennæ; but the mouth feelers or palpi are also organs of touch and tactile hairs may occur on any part of the body or its appendages. No one insect species has all these senses equally well developed, and few have more than one or two really so specialized as to be conspicuous. There are more, indeed, which have none of them more than rudimentarily present and probably a fairly well-developed general sense of perception is enough for the majority. Such a sense enables the insect to recognize the vibrations that mean food, a mate and a place to oviposit and that is all that is really necessary to enable it to fill its place in life. As to that tactile sense that implies a recognition of what we know as pain, I believe it to be very feebly developed. I do not indeed assert that insects are insensible to pain; but all observations indicate that they appreciate it very little and very temporarily: real suffering I do not believe them capable of at all.

An interesting question that is often raised in this connection is whether insects reason or whether all their actions are instinctive. I do not believe that any one can study insects at all closely without crediting them with a certain amount of reasoning power. Some species do such incredibly stupid things occasionally that it would be a libel on instinct to charge it with such actions, and often specimens of the same species will do things so differently that individuality and ratiocination must be accepted as accounting for the difference. To be sure it is not a very high grade of intelligence that is manifested, using our own attainments as a standard; but it is such a grade as brings out the difference between individuals and species and enables one to do well what the other fails in, habitually. It is in the *Hymenoptera* and especially among the social forms that this intelligence is best manifested; but I have noted it in the majority of the species that I have observed at all carefully in the open, under natural conditions rather than in the laboratory in artificial surroundings.

Insects are as a rule prolific breeders, although there is a great difference between them in this respect: some multiply only ten-fold in the course of the season, while in others the capacity is 1,000,000,000 descendants in the same period. No one has actually counted that number, of course, but we have counted the number born to a single pair and determined the number of broods to the season; so it is a mathematical certainty, even if, as a matter of fact, probably no one pair ever matured all its offspring for as many successive generations as are required to produce such a result.

In their development there is considerable variety, but as a rule they pass through four more or less distinct stages: this being called transformation or metamorphosis, while the various stages are also called instars.

The first, or egg-stage, is usually quiescent and generally passed outside the insect body; but in some cases it hatches within the ovary of the mother and young are born alive, as in many plant lice and scale insects. Species may therefore be oviparous (egg-bearing), or viviparous (live-bearing), the latter also termed larviparous.

The second, or larval stage, is that which hatches from the egg, and it may or may not be like the parent. In the grasshopper, for instance, we can recognize it as such, no matter how recently hatched; but in the minute caterpillar, just out of the shell, no resemblance to the butterfly can be traced. The larval stage is the period of growth: the insect feeds to the limit of the elasticity of its integument or outer skeleton, then sheds this skin or "moults," and repeats this process until it has reached its limit of size.

It may be well to say just a few words as to this outer skin which forms so important a feature in the insect structure. It is soft yet resistant, and may become so resistant that it is almost impenetrable to corrosives or oils and with difficulty to be punctured with needle or knife. It all depends upon the amount of chitin deposited in the tissue and chitin is a secretion from the lower layers of the cuticle, resembling horn in texture and somewhat in qualities. No matter

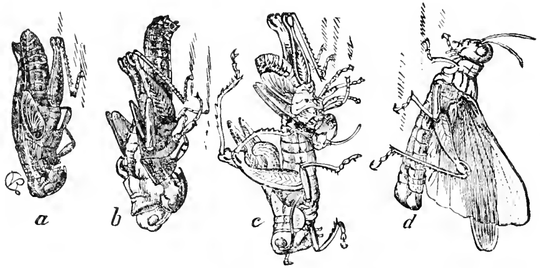

FIG. 2.—Moulting of a grasshopper: *a*, nymph ready to change; *b*, the skin split along the back and the adult emerging; *c*, continues the process, and at *d*, the insect is drying out.

how soft the body wall it contains some chitin and as this is not elastic, there is a limit beyond which it cannot be stretched. When this limit is reached a new skin forms beneath the old one which, thereupon becoming lifeless, splits and permits the larger next stage to escape. This sort of change is found also in the crustaceans, and in some of the reptiles.

The third, or pupal stage, may be a period of rest or of continued activity, depending upon whether the species has a "complete" or an "incomplete" metamorphosis. Returning again to our young grasshopper, usually called a "nymph" rather than a larva, when this has become ripe, it develops wing pads or rudimentary wings; but continues its feeding as in the preceding stages until the period when it moults for the last time and changes to the adult or fourth stage. It thus develops continuously, without conspicuous change of form, and the metamorphosis is incomplete. Our caterpillar, however, after moulting as often as needed to obtain full size, changes into a nondescript creature bearing no close resemblance to its former nor to its future stage and remains in this "pupal" or "chrysalis" form while the caterpillar structures are disintegrated and re-formed into butterfly parts. This is a complete transformation, in which almost no part of the larval structure remains unchanged, and even the method of feeding may become completely reversed: indeed, in some cases the adults never feed at all, depending entirely upon the supply stored by the larva to mature the reproductive cells or eggs.

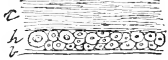

FIG. 3.—Section through insect crust showing layers of chitin at *c*, the cellular layer at *h*, and the basal membrane at *b*.

Among themselves insects differ as much in appearance and habits as they do from their more remote relations. They are found wherever life is capable of existing at all, and there is no organic substance known which, in one stage or another, is not food for some insect. They are moderately numerous, some 200,000 different kinds being already known and described, with the reasonable certainty that we have not yet discovered much more than one-half of those that exist.

There are some that never become winged; that are soft-bodied in all stages, live usually in damp places and are simply organized: these are the *Thysanura*, in which the mouth structure is not well developed.

A very decided advance is found in those insects that gain their food by sucking it through a jointed beak by means of slender, bristle-like lancets in all stages; and these are the *Hemiptera* or true bugs.

Grasshoppers, roaches, crickets and the like have the hind wings folded in longitudinal plaits, laid straight under the covering primaries, and are hence called *Orthoptera*. They chew their food and are often troublesome to the agriculturist.

Another large series has the wings thin, transparent, usually of good size, with numerous longitudinal and transverse veins like a net or reticule and hence called *Neuroptera*. This is the most primitive of the winged orders of biting insects, and shows a great diversity of forms and grades of development. The dragon flies serve as a well-known illustration of one type. The very general definition of the order here given covers a series of remnants that are elsewhere more particularly specified. It was in the Neuropterous or net-winged type that the great break-up among the mandibulate insects occurred and variation ran in many directions. Some of the lines flourished for a little time only; they proved ill adapted to their surroundings and survive only by a few families and genera in which the species are usually well fixed and easily distinguished. Others, well suited to live, proved barren when it came to adapting themselves to new or a variety of conditions. These are fairly numerous even now in families, genera and species; but their limit of adaptation is reached and they are shoots from which no further branches may be expected. From the other lines the modern dominant orders developed which, rich in forms, show species capable of living under the greatest conceivable variety of conditions.

The *Coleoptera* or beetles are known by the hard

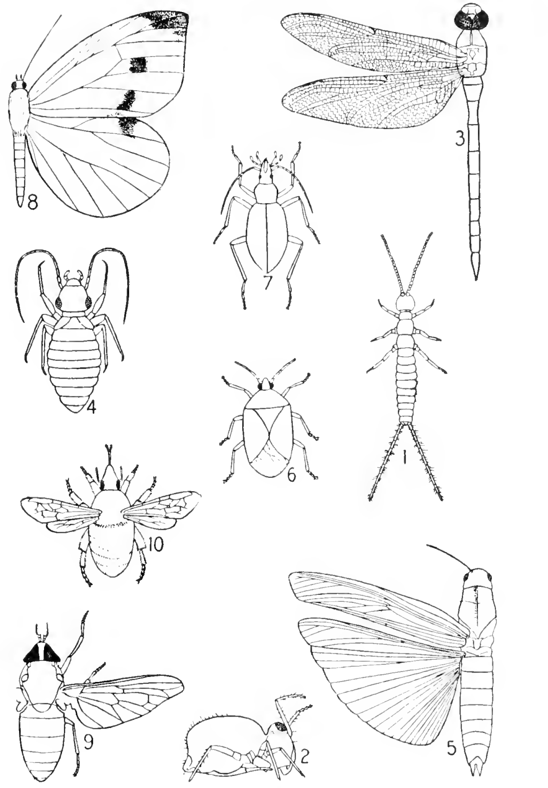


FIG. 4.—The orders of insects: 1, a bristle tail and 2, a spring tail, are *Thysanura;* 3, a dragon fly and 4, a Psocid, illustrating *Neuroptera*, 5, a grasshopper, illustrating *Orthoptera;* 6, a shield bug represents *Hemiptera;* 7, a ground beetle shows *Coleoptera;* 8, a butterfly, illustrating *Lepidoptera;* 9, a horse-fly represents the *Diptera*, and 10, a bumble-bee, the *Hymenoptera*.

or leathery fore-wings, beneath which the membranous secondaries are transversely folded. They gain their food by chewing, in all stages, although the early or larval forms are usually altogether unlike the adults.

The *Lepidoptera* include the butterflies and moths, known by the scaly covering of the wings. The scales appear as fine, dust-like particles that are easily rubbed off; but under the microscope show great differences in form and color. In this order the mouth parts of the adult are modified into a coiled tongue capable of sipping liquids only; but in the larval stage the caterpillars are voracious devourers of plant and other tissue.

Bees, ants, wasps and the like belong to the order *Hymenoptera*, in which the wings are transparent, with few and often no veins; never reticulated. Many of the species are of extreme interest because of their social habits and organizations, and the honey bee is of direct benefit to man in more ways than one.

Finally come the flies; differing from all other insects by having only one pair of wings, whence their ordinal name *Diptera*. We shall have more to say concerning some of their species and development elsewhere.

The insects as a whole are at the top of the line of development in the *Articulata;* they diverged early from the worm-like ancestors and their remains, already well developed, are found in the earliest fossil-bearing strata. At the present time there are more species of insects than there are of all other species of animals taken together, and in number of individuals they are unapproachable. The class as a whole is yet a growing one and both genera and species are in some orders unfixed and in process of formation. There is no better field for the study of animal variation, and the problems imposed upon us by them have scarcely begun to be appreciated.

# CHAPTER II

## THEIR RELATION TO PLANTS AS BENEFACTORS

While, in a general way, insects frequent plants merely to feed on them, yet this feeding is not necessarily destructive and may even contain an element of advantage. Hence we find that, far from developing structures to repel, many plants produce attractive flowers and secrete nectar as an invitation to insects to call upon or visit them.

Flowering plants as a rule have two kinds of sexual organs: the pistil connected with the seed or female element, and the stamens, producing the pollen or male element. Fertilization takes place when the pollen or male element is brought into contact with the receptive surface of the pistil, and this pollination may be produced in many different ways. Sometimes the same flower has both pistil and stamens, and the pollen from the latter may be discharged so as to come into immediate or direct contact with the former. But this is not always the case, for the pistil may not reach the receptive condition until after all the pollen has been removed from the stamens and, on the other hand, the pistil may become receptive before the pollen on the same flower is mature. In such cases there must be pollination by some outside agency. Many flowers are of one sex only, *i.e.*, either pistillate, bearing female organs only, or staminate, bearing male organs only: and sometimes an entire tree or plant may bear flowers of one sex only. Here again pollination by some carrier is necessary and among the carriers the most active agents are the wind and insects.

Plants which depend upon the wind for pollination usually produce a light pollen in great quantity, so that at times the air may be full of it. Plants which depend upon insects for pollination may produce much or little; but it is usually somewhat sticky so as to adhere readily to the body or vestiture of the visitor. And as insects are not altruistic enough to call on the flowers merely to benefit them, some sort of attraction must be offered

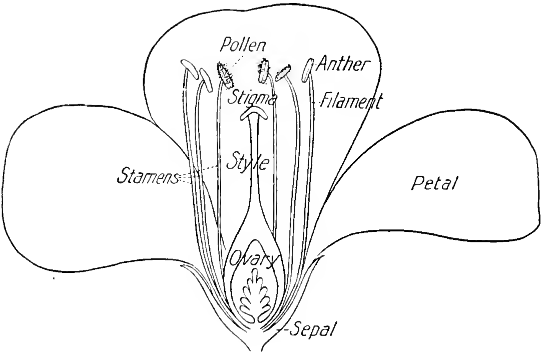


FIG. 5.—Section through a flower. illustrating the reproductive parts.

to invite the visits. This attraction may be in the shape of honey or nectar for those species who seek for themselves alone, or for their progeny; or in the shape of pollen suitable for use as food directly or in preparing food for the young of the visitor.

Where nectar alone is relied upon to attract, it is usually stored so as to compel the insects to come into contact with the reproductive organs in their efforts to reach it; and in such cases, not infrequently, the flowers are modified to invite special kinds of insects only.

For instance, the clovers are especially adapted to attract long-tongued bees; flowers like the *Petunia*, the evening primrose or the jimpson weed attract the hawk-moths, whose long, flexible tongues reach to the nectar cups at the very bottom of the deep florets.

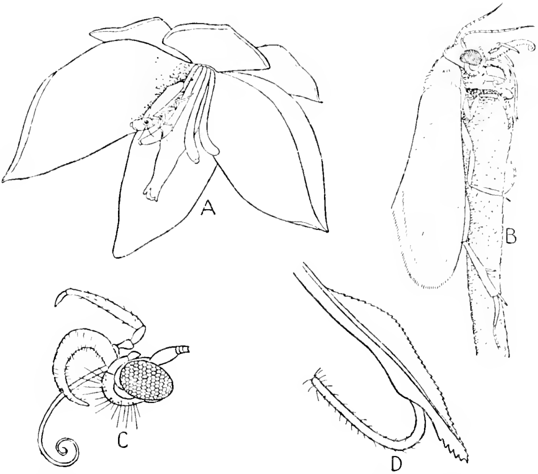


FIG. 6.—*a*, Yucca flower with moth in position, ovipositing; *b*, *Pronuba* gathering its pollen mass; *c*, head of *Pronuba* from side showing the maxillary tentacle; *d*, tip of the ovipositor.

So far as the insects are concerned the pollination is a mere incident in most cases: it occurs because the flower is so built that it must occur when the pollen or nectar is gathered. But there is at least one case in which it appears almost as if the insect acted intelligently, with a definite purpose in view, and the demonstration of this case we owe to the careful observations of Dr. C. V. Riley, erstwhile Entomologist to the U. S. Department of Agriculture.

The flowers of the species of Yucca are absolutely incapable of self- or wind-pollination, and the stigma is so situated that no ordinary insect visitor can reach it in a casual search for food. In some localities, it was observed that the common Yucca or soap-weed never produced seed and that wherever seed was produced, almost every pod was infested by a little caterpillar that destroyed a greater or less percentage of the seeds. The parent of this caterpillar is a small white moth, the *Pronuba yuccasella* of Riley, in which the mouthparts are curiously modified and utterly unlike those of any other moth species that we know. At the sides of the ordinary tongue there are developed a pair of flexible processes set with little pegs and spines, and capable of being coiled like the tongue itself. When the female, which alone has these processes, is ready to lay an egg, she enters a Yucca blossom, gathers a little mass of pollen, rolls it into a ball, carries it by means of the coiled processes to the pistil, and rams it down so as to bring it into direct contact with the receptive surface. Not until this has been completed does she turn and then, into the ovary or embyro seed pod, she forces an egg by means of a slender, sharp-pointed ovipositor. She is now ready to repeat the process on another flower and she does repeat it until her stock of eggs is exhausted. Here we have a deliberate pollination preceding oviposition, as if the insect knew that it would be useless to lay an egg until the possibility of development in the seed pod was assured.

This peculiarity, though confined so far as we know to the genus *Pronuba*, is not confined to one species only. There are a number of Yuccas in the country, including the giant or tree Yuccas of the southwest, and for every species of Yucca there is a species of *Pronuba*. Surely a most wonderful adaptation of insect and plant, neither of which can now exist without the other.

And yet, while the adaptation is not so specific, nor the evidence of design so apparent, the dependence of red clover upon long-tongued bees is not less absolute. Australia has no native bumble-bee, and red clover was unknown there until the colonists began to cultivate it. There was no difficulty in making crops of forage; but it would not seed. Importing seed annually was expensive and, naturally, the Australians were anxious to raise their own. This led to a study of the reasons for the failure, in the course of which the dependence of the plant upon bumble-bees was established. The remedy was obvious, and now European bumble-bees disport themselves among the Australian red clover, seed is plentiful, and interference with bumble-bees is a crime—as it should be rated everywhere.

Bees, by the way, are the most universal pollenizers, and are highly specialized for that purpose. All bees are more or less hairy: sometimes conspicuously so, a dense woolly clothing appearing all over the body; sometimes sparsely, the hair being often localized. But whatever the bee, and however scant its clothing, the hair is always compound: spurred, branched or even plumose. In some series it is so strikingly characteristic, that from the hair alone, the genus to which a bee belongs can be determined with reasonable certainty. In all modifications and adaptations, be they small or great, the pollen-gathering function is always attained: for bees need pollen in their domestic economy. Most insect mothers have no more care for their offspring than to place the egg in some position where the larva, when hatched, will find food. In the *Hymenoptera*, to which the bees belong, storing food upon which the larva feeds is a common occurrence, and the larva, when hatched, finds surrounding it sufficient nourishment to bring it to maturity. In the social forms, matters have developed yet further, and the larva does not even feed itself: it is fed by the mother or a nurse, and its food is prepared beforehand; either a mixture of pollen and honey, or fragments of insects mixed with salivary secretions of the adult. And so bees need pollen as food for their larvæ, and upon the mothers or females falls the burden of gathering and storing it. For convenience we consider as females those sexually undeveloped forms in the social species which we know as workers, and in that sense all the female bees are supplied, not only with gathering hairs, but with some sort of structures to carry the pollen. In the common hive-bee the inside of the first joint of the hind foot or tarsus is modified into a curry-comb-like structure for cleaning the pollen grains out of the hair, and the outside of the hind tibia is provided with a fringe of long hair forming a basket into which the pollen is packed for transportation. In other bees other parts of the legs, of the breast, or even of the abdomen are provided with means of transporting pollen loads, and so after a visit to the first flower the bee is fitted for its mission of fructification, which occurs as a mere incident in the gathering.

There is no group among the insects that is more interesting as a subject for study than that containing the bees. Not only are the structures of adaptation very beautifully developed for their purpose; but their life history is often of intense interest. On the honey bee alone we have not only the vestiture, the pollen carrier and the brushes that clean out the pollen from the hair; we have, in addition, the antenna-cleaner on the fore leg and the complicated mouth parts. The

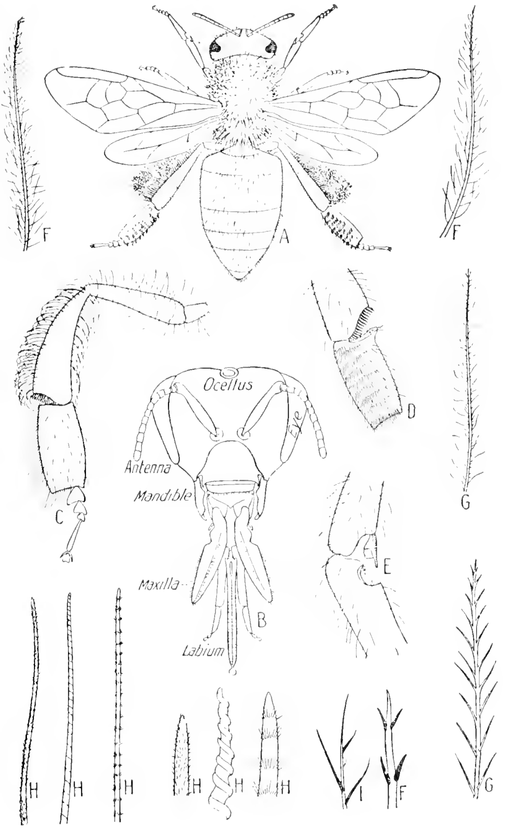


FIG. 7.—Bee structures: *a*, honey bee, pollen loaded; *b*, mouth parts of a long-tongued bee; *c*, hind leg of bee showing pollen carrier; *d*, wax cutter and curry-comb of 1st joint of hind tarsus; *e*, antenna-cleaner of fore leg; *f*, hair of bumble-bee; *g*, hair of *Melissodes*; *h*, hair of *Megachile*; *i*, hair of *Xylocopa*.

antenna-cleaner is a little notch on the inner side of the basal joint of the front tarsus, set with fine teeth and closed by a spur from the end of the fore tibia. When the bee desires to comb out the vestiture of one of the feelers, the fore leg is brought up, the notch is hooked over the stem at base, the spur is brought to the lock, and at a single sweep the entire series of joints is brought into condition. It is all very simple and very neat, and could not be better adapted for its purpose if designed by man himself. The mouth structures which are also kept in condition with this apparatus merit a little further attention.

I have already alluded to "long-tongued" bees and this has carried with it the suggestion that there was a difference in that respect. As a matter of fact there is every intermediate form between the tongue of the bumble-bee, more than half as long as the insect itself, and the little digger bee, whose labium or lower lip does not extend beyond the edge of the mouth. It is not always easy for the novice to recognize to which division a bee under observation belongs, because the long tongue is usually hinged, and may be drawn back against the breast in such a way as to be protected from danger of injury. When fully extended the mouth has, laterally, a pair of very well-developed mandibles, which usually serve more as tools in building homes than as organs for securing food. Between these mandibles, and completely separated from them, is a pair of sheath-like structures which are generally pointed at the tip. These are the maxillæ, which are not of much active use, though they are the organs by means of which ripe grapes and other fruits are occasionally punctured when normal supplies are scarce. In the very centre is the flexible tongue itself, ringed in structure, with series of hairs round about it, and a little button of hair at the tip. This is the structure that is forced down into the very heart of the flower and forms a lapping organ, by means of which every particle of nectar may be secured. The bee is not really a sucking insect at all; but gets its food by lapping somewhat after the manner in which a dog laps water.

Only the honey gatherers have tongues of this type. Bees and honey are usually associated, but as a matter of fact many kinds gather no honey at all, and very few of them store it. In the species in which there is no elongated central tongue, this is replaced by a short bladder-like organ, also set with more or less spatulate hair, suited for lapping, but not for getting down into deep flowers. Bees of this sort we find on our shallow flowers like those of the strawberry, blackberry and other *Rosaceæ*, and many of these gather no honey at all.

It is a delightful pastime, although not always easy, to investigate the domestic economy of the various bees. Some of them make nests or cells of mud gathered from road-side puddles; some bore into twigs, branches or even boards and in the tunnels so chewed out form the cells in which a brood is raised; some make cells of wax in cavities of trees; others seek a cavity under the turf, and in a mass of pollen raise their brood with little attempt at making cells of any kind; and yet others dig down deep underground, five or six feet below the surface and, far from the light, build the homes in which their young are developed. And when we find a bee-home, we can always recognize it by the character of its store. It may be a cake of solid pollen, packed hard in a definite, loaf-like form, or it may be a semi-liquid mass of mixed pollen and honey, so arranged that the larva may feed on, without being imbedded in, it. But always there is pollen, and the pollen gatherer is always also a plant fructifier.

There are many others among the *Hymenoptera* that are useful in the work of pollination because of their habit of feeding among the flowers, even if not on them; but all this is based on the same visits which the flower encourages and of which it takes advantage; but no account of this sort of relationship could be considered even passably complete, without some reference to the complicated relationship existing between the Smyrna fig and the minute little *Blastophaga*, a species whose life relations have been beautifully worked out by the Entomologists of the United States Department of Agriculture.

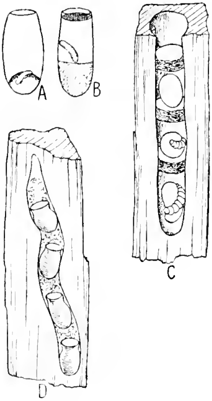

Fig. 8.—*a*, cell of *Augochlora* with egg laid on pollen mass; *b*, cell of *Andrenid* with egg resting on mixture of pollen and honey; *c*, cells of carpenter bee in wood; *d*, mud cells of mason bee in burrow—*c* and *d*, after Packard.

The Smyrna fig of commerce depends for its edible quality upon the ripened seeds that it contains. The fig is not really a true fruit as that term is generally defined, but is a thick fleshy envelope within which the flowers are contained. In the Smyrna fig these flowers are all female and no pollen is produced anywhere on the tree. Left to themselves, such trees could never produce ripe fruit, and that was the condition of the Smyrna fig orchards in California, prior to 1900. In the Mediterranean countries, whence our commercial supply is generally derived, there are found beside the cultivated also several varieties of wild or caprifigs, which produce three crops of fruit during the season. These fruits contain male flowers, producing an abundance of pollen; but this pollen is never naturally discharged from the envelope containing the florets.

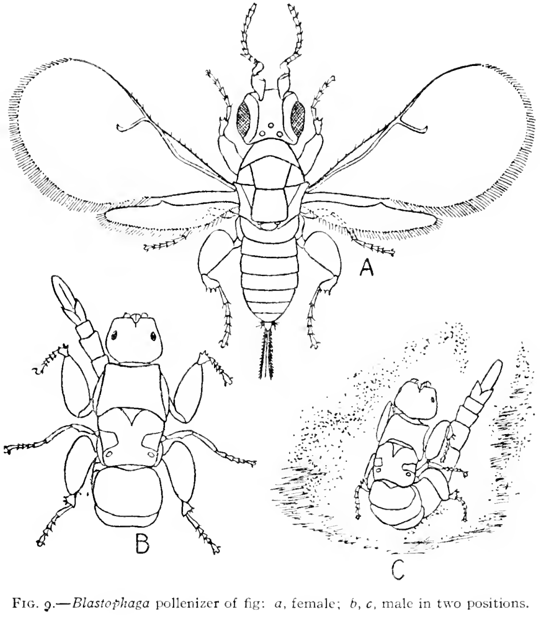


FIG. 9.—*Blastophaga* pollenizer of fig: *a*, female; *b*, *c*, male in two positions.

Yet it was recognized by the fig-growers in the Orient that to obtain fruit of the commercial edible varieties, it was necessary to bring to them when in bloom, branches containing fruit of the caprifig, which were usually hung up in the tree which it was intended to fructify. This work of pollination is accomplished by the *Blastophaga* already referred to, although, far from benefiting itself in the process, the insect dies without even being able to continue its kind.

In the caprifigs the female flowers are replaced by little gall-like swellings in which the larvæ of the *Blastophaga* develop. One generation of figs, the so-called "mammæ," remain on the trees during the winter and by the time they are ready to drop, there is already on the trees a new or spring crop of fruit, known as the "profichi." By the time that this crop is in proper condition, the insects that have hibernated in the "mammæ," are fully developed, the wingless and almost blind male *Blastophaga* has fertilized the female before she is even out of her cell, and the latter, leaving the dried-up fig by the small anterior opening, makes its way into the new figs, to provide for a new generation. In the "profichi" this generation matures at the time the commercial Smyrna fig is in proper condition and the females, emerging pollen covered from the "profichi," enter the small opening of this true female flower receptacle, if they find themselves in a tree bearing them. But in this Smyrna covering all the female florets are fully developed, and the gall-like swellings that replace them in the caprifigs are absent. The insect therefore moves about over the entire interior surface of the pouch, seeking a place to oviposit, and in the process distributes its load of pollen everywhere. It eventually dies without reproducing, and usually without even being able to make its way out again. But though the insect has lost its life, the tree has gained and the seed pouch that we know as the fig, comes to maturity and ripens seed.

At the same time that the Smyrna fig which produces the edible commercial fruit is in bloom, there is also another crop developing on the caprifigs, and these are known as "mammoni." The *Blastophaga* issuing from the "profichi" on the same tree, naturally enter these fruits which are of the same character as the preceding crops, and are able to continue their kind, coming to maturity when the third crop is ready for their reception. This third crop represents the "mammæ" or over-wintering form, from which the "profichi" of the following season are again entered by the *Blastophaga*.

Here we have an extremely complicated relationship which, reduced to its simplest terms, means that in order to produce the commercial Smyrna fig there must be suitable caprifigs producing "profichi" infested by *Blastophaga*, at a period corresponding to the development of the female flower capsule. And as the insects are very small and very frail, the caprifigs must be either well distributed among the Smyrna trees, or the infested "profichi" must be gathered and distributed among the trees to be pollenized.

The accounts, published by Dr. L. O. Howard in the Bulletins and Reports of the U. S. Department of Agriculture, make interesting reading and show how, after many trials and much painstaking investigation, the *Blastophaga* and the necessary caprifigs were finally introduced into the fig-growing districts of California, and how a new industry, absolutely depending for its continuance upon a minute hymenopterous insect, was finally established upon a firm and scientific basis.

How many cases of this kind exist among plants having no present economic value it would be difficult to estimate, and how so complicated a relationship ever became established is not yet explainable even by a theory.

The *Lepidoptera* have been already incidentally referred to as pollenizers and they rank, as an order, next to the *Hymenoptera* in importance. Butterflies and moths, when they feed at all, feed only on liquids and most of them on prepared plant juices or nectar. The butterfly hovering over a flower and sipping honey, is a familiar figure, and the visits of hawk-moths to the flowers that open at dusk are fairly well known; but that busy life that stirs among the flowers after night falls, is unknown except to the naturalist who prowls about in wood and field, among the hedges and along the road, often with a bulls-eye lantern like a thief; seeking indeed to surprise some of nature's secrets by artificial light, his organs of sight being far inferior to those of the creatures whom he seeks to study.

That many flowers are most fragrant at night, and that many fragrant, night-blooming flowers are white or without striking colors, is a commonplace to one who knows the country at all; but that this penetrating fragrance is to attract insect visitors at a time when sight does not suffice for an invitation is not so well known. And yet it is at night that the most abundant, albeit almost noiseless, life can be observed on such flowers, and here we will find owlet and other moths busily engaged in probing every floret and incidentally accomplishing nature's aim of reproduction. I say "incidentally" with intent in this case, because neither moth nor butterfly has any use for the pollen that it dislocates and relocates as it moves. It is after food, purely and simply, and that food is nectar: if in reaching that nectar the tongue, pollen laden, is brought into contact with the stigma, that is merely because the insect could not help itself, any more than it could prevent the adhesion of a few grains of pollen from another flower.

Exceptions occur always and that of *Pronuba* in its relation to Yucca has been related; but in general the *Lepidoptera* pollenize as a mere incident and with the tongue, while feeding. And this tongue is a really interesting bit of structure. It is coiled like a watch spring when at rest between the mouth feelers, and no one would suspect its presence or size from an ordinary dried specimen; but when uncoiled it is often as long and sometimes much longer than its bearer, and here again we have that beautiful ringed structure that adapts itself to so many purposes among the insects. There is no flower so deep that its nectaries are beyond the reach of all insects but there are many flowers so deep that only a single long-tongued species is invited. And therefore we have an abundance of species with tongues of less than an inch in length, quite a number that have them from two to four inches and a very few where ten or even twelve inches are attained.

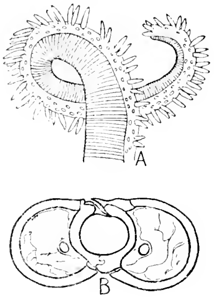


FIG. 10.—*a*, tip of butterfly tongue showing the sensory pits and taste cups; *b*, section through tongue showing division into two halves.

The butterfly tongue really consists of two separate parts or halves, the modified maxillæ, held together by specially developed structures; and the space between them forms the tube through which the liquids are carried into the mouth. Each half contains its own supply of muscles, a large tracheal tube extends to the very end, and there is an excellent supply of nerve-fibres to guide the insect in its operations in the depths of the florets.

Most of the tongue is bare or set with scanty stiff hair only; but at the tips in the different species, are found a great variety of tactile structures, taste cups and gathering processes, by means of which our moth not only recognizes the presence of something good to eat, but manages to get it all, as well. In the adult stage as moths or butterflies, the *Lepidoptera* have few bad and many good qualities; but in the larval or caterpillar stage the reverse is the case. As pollenizers the *Lepidoptera* could be missed much more readily than the bees; none of our cultural plants depending upon them for their continued existence.

Among the *Coleoptera* or beetles there are many that frequent flowers for one purpose or another and many of these are more or less pubescent or covered with hair, so that they may be and often really are much covered by pollen as they move about. And as they move about they do without question add their share to plant fruitfulness; but they are also very often feeders upon them or upon the pollen. In so far as they are pollen-feeders merely, this does little harm, because that is usually produced in great excess; but some feed on the pollen in such a way as to rob the plant of all possible chance of benefit. For instance the strawberry-weevil in the larval stage subsists altogether upon pollen. But the parent beetle punctures the unopened bud, lays the egg in the mass of forming pollen and then punctures the stalk below the bud, so that the latter may never open. This is sheer robbery without corresponding benefit and, on the whole, flowers pay pretty heavily for such incidental advantages as they derive from the visits of beetles. In any case the pollination is purely incidental, for the beetles gather neither pollen nor honey, and the hairy covering is not modified to make it especially serviceable as a carrier.

*Diptera* or flies are often intimately associated with flowers, and many of these are hairy, some even with spurred or compound hair; but none with modifications that adapt them especially or peculiarly as pollenizers. We have one family, the *Bombyliidæ* or bee-flies, resembling bumble-bees somewhat in appearance and quite as hairy, many of which also have a long tongue rivalling some of the *Lepidoptera*. But their habits are quite different. One never sees them buried in a flower or rolling about among the blossoms, pollen-covered. On the contrary they usually hover daintily over bare, sandy areas or, if over flowers, then very delicately and resting lightly when at all. That they are of some use to the plants is probable; but they have no important function. And the same is true of the *Syrphidæ* that are found so often resting on or about blooms: the majority of these are bare, or have only a thin soft vestiture and slender hairless legs to which pollen could not adhere if it would.

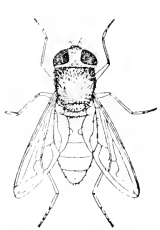

Fig. 11.—Chrysanthemum fly; *Eristalis tenax*.

An exception to this general statement is found in the chrysanthemum or "drone fly," a burly bustling species that becomes conspicuous late in the season and resembles in size, color and general appearance a honey bee, for which indeed it is often mistaken. A little experience, however, shows that it has no sting, and therefore the term "drone fly" is not so inappropriate.

Growers of chrysanthemums believe this fly of great importance in the pollination of that plant and they may be correct; but on other plants or flowers they are of little use. Their habits in the early stages are about as unlike those of the adults as it is easily possible to imagine. The larvæ live in all sorts of semi-liquid excrementitious matter and are known as rat-tailed maggots, because of the long anal process by means of which they obtain air from above the surface of the filthy mess in which they live.

The number of flies known to us is already very great, and the number that still remains to be studied is probably even greater; while as to their habits we know them in the most general way only. There may, therefore, be groups more decidedly beneficial to plants than anything that I have mentioned; but there can be nothing comparable with the bees, since none of the flies store food for their progeny.

The fact is, then, that many plants depend for their reproduction entirely upon insect visitors. Some flowers are so constructed that only very specialized forms can accomplish the function of pollination and there is in many such cases a mutual dependence: the insect cannot exist without the plant nor can the plant continue its kind without the insect. Other flowers issue a general invitation by bright colors, wide open parts, abundant pollen or filled nectaries, readily accessible to anything that may come along. Yet others depend upon nectaries that are attractive, but are so situated that any insect that succeeds in gaining access to them must of necessity pay in pollenizing. And here we come to a subject on which the botanist has his say, and shows how ingenious are some of these plant structures and how well adapted to their end, so that pollination may even be accomplished without the necessity for bringing the pollen into contact with the insect at all, the latter merely releasing the trigger that restrains the distribution of the fructifying material.

There is one other method in which insects are useful to plants, and that is as food. A very few plants are "carnivorous" or feed upon animal food, and that animal food consists mostly of insects; but that is a relation which is extremely simple in character although the plant habit is exceptional.

# CHAPTER III

## THEIR RELATION TO PLANTS AS DESTROYERS

WHILE, as has just been shown, there is a mutual interdependence of plants and insects in which both may be benefited, or if one is harmed, the benefit derived is so far in excess of the injury suffered that it does not count against the value of the relation, there is also a kind of dependence in which the insect gets all the benefit, and the plant all the injury.

A vast number of insects depend absolutely upon plants for their very life and give nothing at all in return: they are destroyers pure and simple, using the plant tissue as food, as material to supply protection, or as a habitation. But the amount and character of the injury vary enormously and may either be a negligible incident in the life of the plant, or form the principal check to its growth or cultivation.

We may dismiss with no more than a mere mention that vast horde of insects that gets into plants when they are dead and begin to disintegrate. Nature dislikes dead organic matter, and when a tree or plant is dead or dying, or when decay begins in a sappy fruit or fungus, there are insects among other agents ready to reduce it to that inorganic condition from which it originated. While the actual death of a diseased or weakened tree is often hastened by such insects, they can hardly be said to be enemies in the direct sense; but scavengers, ever ready to begin their office and fostering the condition in which it becomes their legitimate prey.

Beginning with the simplest order, the *Thysanura*, we find few plant destroyers among them. Originating as they did in primitive times when dampness, mud and ooze were prevailing conditions and vegetable life just established, they were fitted to live and gain their subsistence in disorganized tissue: they were simple forms of scavengers, and so they are to-day in most cases. They are always found where there is moist vegetable decay and sometimes, in manure beds, they occur in countless numbers. In fermenting sap, under bark of trees undergoing moist decay, in masses of leaves and similar localities, these species may generally be sought. Their direct influence upon growing vegetation is extremely small.

In the *Neuroptera* there has been an advance, although, as these were also primitive species and largely adapted to aquatic or semi-aquatic life, the vegetable feeders are in the minority. Almost everywhere the larval life is more or less predatory in tendency and in some, like the *Odonata* or dragon flies, this predatory character is carried into the adult stage. The feeders on vegetable matter, like Psocids and Termites, usually attack dry or dead tissue or feed upon Lichens and similar material. None of them rank as destroyers of the higher forms of plant life, although Termites do in some instances attack growing vegetation.

In the *Hemiptera* we have a well-developed series of terrestrial species, the vast majority of which are feeders on plant life or on plant juices drawn from living plants. The mouth structure of the insects is such that they can feed only on the liquid which they draw from a punctured tissue, whether vegetable or animal, and therefore, primarily, the injury is due to a withdrawal of sap, severe in proportion to the amount of liquid thus withdrawn. Secondarily, injury is caused by an interruption of the circulation in the plant, due to a hardening of the exhausted tissue, or the drying out of the cells from which the liquid matter has been abstracted. More rarely a positive poisoning of the tissue occurs, due apparently to the injection into it of the salivary secretion of the insect, and this may result in the death of all that portion of the plant beyond the puncture. That sort of injury is often pro-

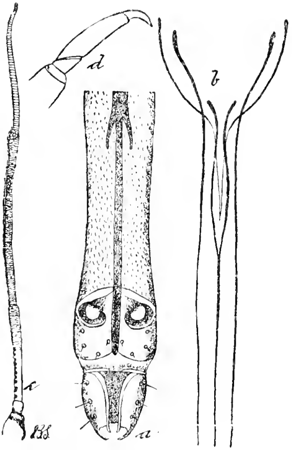


FIG. 12.—Mouth parts of a plant louse—*a*, the jointed beak; *b*, the lancets; *c*, the feeler; *d*, the foot.

duced on succulent plants like the Cucurbs, including cucumbers, melons and the like, or Solanacea, including potatoes, tomatoes, egg-plants, etc., the offenders being mostly plant bugs of the families *Capsidæ*, *Lygæidæ* or *Coreidæ*.

Plant lice are universally distributed and there is scarcely a plant not in some way subject to their attacks.

They are insignificant as individuals; but dangerous in hosts: and hosts grow out of individuals in an incredibly short time, owing to their fecundity. Given a few eggs on the tip of an apple twig in winter, they hatch into young lice as soon as the leaf-buds open and, in a week or ten days, depending upon weather conditions, these begin to bear living young. All the specimens hatching from the winter eggs are parthenogenetic females; *i.e.*, females which do not require to be mated with a male before reproducing their kind; and, when once reproduction begins, it is in the nature of a continuous performance; four, six, eight or more young being produced in a day and for several days in succession. Long before this stem-mother has reached her limit of increase, the first-born daughters, parthenogenetic like herself, have in turn begun the task of multiplication so that, by the time the leaves are fully formed, the surfaces are covered by plant lice, and instead of unfolding and reaching full size, they are curled, twisted and crippled, forming an unsightly mass instead of a beautifully unfolded cluster or tuft. And now we are apt to get a secondary effect due to a peculiarity in feeding. Not content with absorbing only enough to sustain life and to reproduce, the insects gorge continuously and, when incapable of containing more, they eject through the anus a stream of a clear sweetish liquid, known as honey-dew. It was currently believed that the two tube-like structures near the end of the abdomen were the chief organs through which this honey-dew is excreted and they are therefore popularly known as "honey-tubes": more technically they are termed cornicles, which conveys no opinion as to their function. This honey-dew drops upon the leaves below, often in such abundance as to form a complete coating and that, in turn, is an excellent culture medium for a soot fungus which forms a black covering that disfigures if it does not kill the foliage or fruit. It goes without saying that what is true of the apple, which I have chosen for an illustration, is equally true of the cherry, the maple, the orange, lemon or any other tree or plant subject to the attacks of plant lice or others of their allies also producing honey-dew—mealy bugs, white-fly, Psyllids and even some scales.

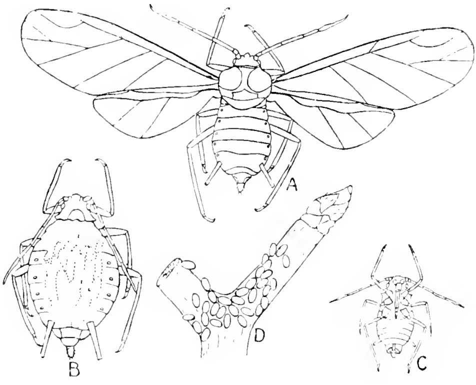


FIG. 13.—The apple louse: *b*, stem-mother; *a*, winged parthenogenetic form; *c*, adult male; *d*, winter eggs on twig.

To return, however, to our stem-mother on the apple, whom we left engaged in the task of increasing her kind. She was born without wings and never acquires them, and her daughters are like her in this respect. But after the second generation matters become crowded, and unless relief is somehow obtained there will be more than can be maintained on the original tree. And so in the third and later generations a variable number of individuals develops further and becomes winged. There is not in this case any generation in which all the individuals are winged, although there are species in which such a condition exists. It is simply that out of a dozen individuals born of the same mother on the same day, a number develop wings and fly away to other trees or plants. They are no further advanced, sexually, than the stem-mother and when they reach their new homes they also produce living young, which may become winged or remain wingless; and this sort of reproduction continues until the end of the season and the gradual decrease of sap in the trees and plants forces a provision for winter rest. Late in the fall, therefore, a generation is produced in which both sexes are represented and from a union of these the winter egg is produced.

Now while this in a way epitomizes the usual history of plant lice, there is an infinite amount of variation. A species that is confined to one tree or similar food plant may do very well without much modification; but a species which feeds during the summer on a plant that dies down completely before winter, needs some provision that enables it to continue its kind elsewhere; hence we have migrations in early summer from and in late fall to the winter host. In a melon field, for instance, there may not be a plant louse until the vines are well developed: then on some warm, almost windless day in June, the air will be found full of drifting, winged aphids and next day a sprinkling of them may be noted all over the melons, giving rise to the summer generations which, in late fall, again produce return migrants that find their way to plants upon which they can pass the winter. Sometimes there seems to be a direct relationship between two plants, as apple and wheat for one form of Aphid that attacks both, or between the plum and the hop, where the insect cannot exist unless both its alternate hosts are present. At other times, as in the case of the melon-louse, the insect has a variety of food plants and the migration is not essential to the continuance of the species. In fact it is not even necessary for all plant lice to go into the egg stage, for some species winter as parthenogenetic females on plant remnants or on stools like the rosettes of cruciferous plants. In tropical countries the resting stage is often during the dry season, when vegetation has little spare moisture.

Some species attack only the roots of plants, and these are usually wingless, and often without honey-tubes or cornicles. Some inhabit the roots at one season and the leaves at another, the winter being usually spent underground, while a large part of the growing period may be passed on the foliage, the spread of the species being provided for there. Such species may be very little modified, like the black species that occurs on peach, or very greatly specialized like the *Phylloxera* that occurs on grape, and is so great a factor in all countries where the vine forms an important part of the agricultural product. This *Phylloxera vastatrix* winters on the roots as a partly grown, wingless form. It grows rapidly in spring and lays eggs, the young from which are, like their mothers, wingless and parthenogenetic, laying eggs and producing others like them in turn throughout the season, always from unfertilized eggs. In most localities, about midsummer, some specimens acquire wings, work their way to the surface and fly to other vines, thus providing for the rapid spread of the species. These winged forms lay from three to eight eggs on the leaves, some of them large, producing females, the others small, producing males. These sexed forms seem to be produced only for the purpose of renewing the vitality of the species for they are without wings, incapable of flight and without mouth parts, incapable of feeding. They are

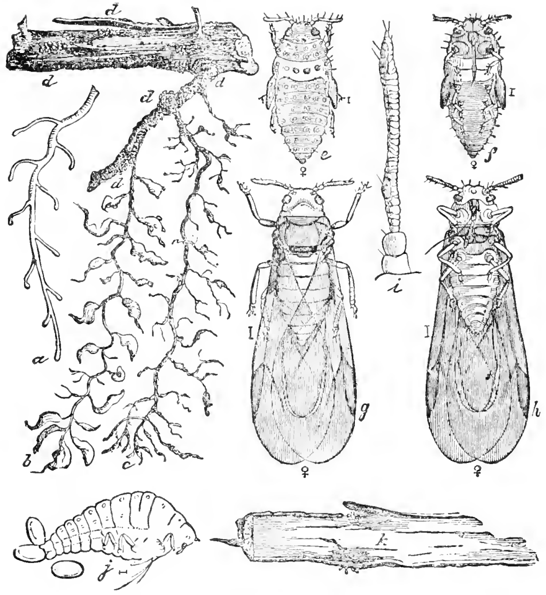

FIG. 14.—*Phylloxera vastatrix*—*a*, sound grape rootlets; *b*, rootlets with newly formed galls; *c*, same with old, dried up tissue; *dd*, groups of lice on roots and rootlets; *e*, *f*, female pupa, above and beneath; *g*, *h*, winged females; *i*, antenna; *j*, oviparous wingless female and her eggs; *k*, root showing location of the eggs.

sexually mature when born, copulate soon afterward, and each female produces one egg which hatches into a form similar to that which started the cycle in spring. But the winged form is not essential for this renewal, for at any time during the summer the underground forms may lay eggs of two sizes producing similar sexed forms that act precisely as did those above ground. So, some of the parthenogenetic forms may leave the roots and crawl up the stem to the foliage, where their progeny form those characteristic galls which strike terror into the heart of the European viticulturist, while they are frequently not even recognized by the vine-grower of the eastern United States. Nor is this leaf-form a necessary feature in the cycle and it does not occur in all localities, so that outward indications of *Phylloxera* infestation may be completely lacking except in the condition of the vine. The *Phylloxera* are gall-makers as a rule, and on the roots of grape produce swellings and distortions which, on vines not accustomed to them, result in the death of the roots or serious disturbance in function, so that the vines sicken and may die. In the original home of the species in eastern North America no especial injury is caused; on the Pacific Coast injury may be severe, but the insect does not spread readily, and so its march may be checked; while in European countries the native vines succumb very easily to the attack of the insect and its spread is rapid where energetic measures for its destruction are not resorted to.

There are other species of plant lice producing galls: some on hickory make bladder-like structures of considerable size, and others produce ridges aptly compared to a cock's comb, on elm. In fact, from the simple distortion produced by a feeding along the veins on the under side, to characteristic bladder-like structures, every sort of intermediate form exists, and as a rule these produce no very serious results on the plant. It is astonishing how great a number of such insects a plant may support without interfering with its power to maintain life and reproduce its kind; which be it noted, is quite a different matter from an injury which will make the plant unprofitable to the farmer or fruit-grower.

Scale insects are close allies of plant lice in many ways and yet totally different in many others. The popular name is derived from the fact that most of the species have the appearance of a fragment or scale of tissue plastered upon or against the bark or foliage of the plant attacked. And so we have soft scales and armored scales, which differ radically from each other. In the soft scales, so named because the outer covering is usually waxy in texture, the outer covering or scale is part of the insect itself, not separable from it in any way, and the term, scale insect, is strictly correct. In the armored scales, on the other hand, the scale or covering mass is tougher, more parchment-like, and forms no part of the insect, although produced or excreted by it. It is possible, therefore, to lift the scale without in any way interfering with the creature beneath it; the covering being formed in part by the cast skin of the insect and in part by a fibrous excretion from special glands.

Scale insects, like plant lice, are capable of enormous feats in the reproductive line, one thousand million descendants for a single pair, during a single season, having been figured out for one of the species! Thus, given a scale introduced without natural checks into a region where conditions favor it, and the effect upon its host-plant can be readily imagined. The practical experience of the Pacific Coast with the cottony cushion scale on citrus fruits, and of the Atlantic Coast with the San José scale, are recent instances that illustrate the destructive powers of scales; the first a soft, the latter an armored form.

Scale insects feed on the juices of their host as do the plant lice, differing in the fact that they are more or less fixed to a single spot on the plant: absolutely fixed in the armored scales, with a very limited range of motion during a part of their life in the soft scales; the latter being in some cases not far removed from the mealy bugs which are active throughout their life and produce a powdery material that does not form a complete covering. Some produce living young and breed throughout the season, like the San José scale; others are oviparous and have only one distinct brood, like the cottony maple scale. In some there are only a few eggs, in others they are almost uncountable, and thus there is a great range in the life cycle, although the nature of the injury done is always the same.

One characteristic feature is the difference between the sexes. The males, throughout the *Coccidæ*, are very minute, frail, two-winged creatures without functional mouth parts and two pairs of eyes; one pair replacing the lost feeding organs. These males are often furnished with long anal styles or filaments, and their only function is to fecundate the female. The latter feeds throughout life, never becomes winged, and her dead body often serves as a cover or shelter for the egg mass that she produces.

The injury caused is primarily due to the abstraction of sap; but quite a number of species produce a distinct poisoning of the bast or bark tissue, often evidenced by a red or purplish discoloration. Where this occurs the twig or branch dies sooner or later. Sometimes pits or depressions are formed where a little group of scales is lodged and, in fact, there are infinite variations in the character of the injury, due to the peculiarities of the plant attacked and to the method of feeding by the insects. Some of the soft

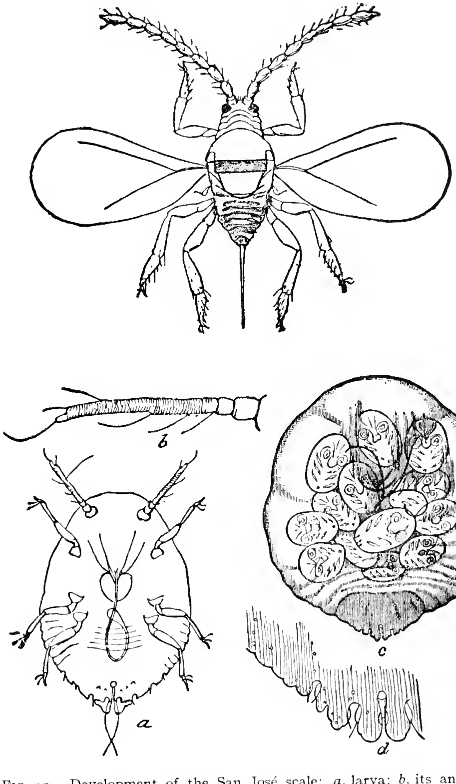


FIG. 15.—Development of the San José scale: *a*, larva; *b*, its antenna; *c*, female with young showing through body wall; *d*, outline of anal plate; *e*, male adult.

scales produce honey-dew in great quantity, and the resulting soot fungus does almost as much injury as the insect. In the olive and citrus groves of the Pacific Coast, trees infested by the black scale are often recognizable as far as they can be clearly seen, and discoloration of fruit is a distinct element of the injury caused.

Quite a number of others among the allies of scales and plant lice produce honey-dew and its consequences, and there is a long series of species, including the leaf-hoppers, tree-hoppers and others of the Homopterous section, that cause more or less injury to their food plants by the direct robbery of the vital juice or sap; but there are none differing so greatly from the methods of plant lice and scale insects as to require special attention here.

A somewhat different type of injury is caused by some tree-hoppers and Cicadas or harvest flies. These do little or no harm by direct feeding; but utilize the twigs and branches of the plants on which they live as places of deposit for their eggs in such a way as to kill or severely cripple them. Some of the tree-hoppers cut little slits in the twigs to receive their eggs, and these slits never heal. The tendency is rather to an enlargement of the scar which permanently weakens the shoot and sooner or later causes a break. The chief sinner in this direction is the periodical Cicada, better known as the "17-year locust," and wherever and whenever that makes its appearance in numbers, the tips of the forest trees in early fall show brown ends as if a fire had passed over them. In such forests it means only a moderate pruning and no real injury to the trees; but in orchards, especially of young trees, injury is often severe, weakening the shoots and branches so that they break under a load of fruit. And these punctures also refuse to heal, and remain permanent sources of weakness, apt to result in a break at any time. I would never advise planting a nursery tree whose trunk had been used by Cicadas for ovipositing.

In the Heteropterous series the species are usually larger; but the life histories are simpler and the injury is not materially different. Here, among the plant

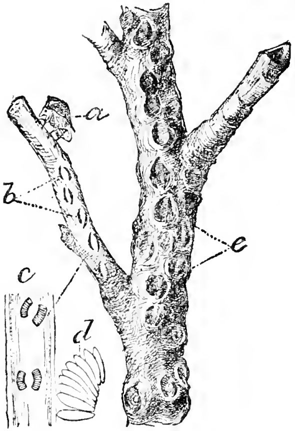


FIG. 16.—*a*, *Ceresa bubalus*, a tree-hopper, ovipositing in slits *b*; the eggs, *d*, arranged as at *c*; old scarred punctures at *e*.

bugs, the poisoning effect already referred to is often noticeable, and is frequently of more importance than the exhaustion caused by the direct feeding. The chinch-bug may serve as the best known example of the destruction causable by these species and of the results that come only from the enormous numbers in which they feed. There is nothing here but a direct loss of vitality due to the abstraction of the plant juices.

The order *Orthoptera*, as a whole, consists of plant feeders: from the earwigs to the crickets there are only a few groups where vegetation is not the chief or only food. The earwigs are curious because of their resemblance to beetles and their large anal forceps, and they feed largely in, though not always on flowers. Not many occur in North America and their chief interest lies in the fact that the female broods over her eggs after they are laid: an altogether unusual character in this series of species. The roaches are not normally troublesome to growing vegetation and are of most interest as household pests, where more is said of them. The *Mantidæ* or graspers is the only group of distinctively predatory species in the order and they are very few in number. The *Phasmidæ* or "walking sticks" are devourers of plant tissue, interesting because of their resemblance to the twigs and leaves among which they live, and because of their habit of dropping their eggs to the ground without care as to their location and future; as far removed as possible from the habit of the earwigs. Their injury to the plants is of the simplest possible description and confined to a partial destruction of foliage, which means little or nothing to the plant.

The grasshoppers, on the other hand, are among the best known of plant destroyers. Under the name "locusts" their ravages have been written of in the Bible and by later writers on conditions in Africa and the Mediterranean countries. The migratory locust has thus come to represent the very type of destructive invasion, and the Rocky Mountain locust or grasshopper in our own country is not less well and unfavorably known for its injuries.

The short-horned grasshoppers, which are the species now under consideration, quite usually lay their eggs in little masses in holes in the ground, which they bore with the horny valves at the end of the body, and they select moderately firm, dry ground for that purpose. Much moisture is dangerous or even fatal to the eggs, hence it is in desert or semi-arid countries that they are most abundant. Such conditions in our country exist among the foot-hills of the Rocky Mountains and no place that I have ever seen exceeds that region in the variety and abundance of its grasshoppers in a normal season. Sometimes, when conditions become unusually favorable, grass-

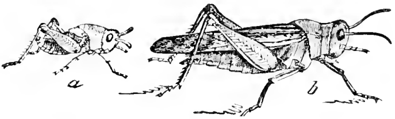


FIG. 17.—The American grasshopper or locust, *Schistocerca americana*.

hoppers may become so very abundant that the vegetation in their native locality is insufficient to support them, and then some species better fitted for flight than others, take wing and seek new feeding grounds. Some are unable to get very far, and rest as close to home as they can, starving if they get beyond the limits of their strength without discovering new pastures; but other, longer winged species, accomplish hundreds of miles from the Rocky Mountains to the Mississippi Valley, alighting first where cultivated lands begin. Thus Kansas, Nebraska and the Dakotas were preeminently sufferers from grasshopper invasions, and not infrequently conditions were sufficiently good there to permit the insects to lay their eggs, providing for a brood which the year following destroyed the vegetation while still unfledged, and then migrated yet further east to do destructive work as adults and to perish gradually, in the egg stage, in the moist unsuitable soil. No one who has not seen grasshoppers in this western country can form any real idea of their actual abundance, and their destructiveness has been the theme of many a writer. They eat any green thing if they must; but favor the low plants of field and meadow so long as they last.

Conditions now are much better than they were and can never again be quite as bad. A large area of what was at one time ideal breeding ground, is now irrigated and under cultivation, and the enormous belt of alfalfa and other crops now basing the foothills, checks and takes up the migrating hordes that occasionally start from the uncultivated areas. The march of advancing cultivation spells the doom of some of these grasshopper species, as it has that of many another animal; but meanwhile the grasshopper is putting up a good fight and is still causing trouble.

While there is considerable variation in grasshopper habits and life history, some of them laying their eggs in soft or decaying wood tissue, there is little in the character of the injury caused; it is always a direct eating of the plant, rarely threatening its life, however much it may be injured for agricultural purposes.

The long-horned or meadow grasshoppers are most abundant in the places shunned by the short-horned species. They delight in moist meadows, in reedy open swamps, and are abundant in the marshes along the sea and lake coasts. They are usually of some shade of green in color, and have a more or less well marked blade-like ovipositor, by means of which they lay their eggs in the stems or leaves of the grasses and other vegetation among which they live. They are largely seed feeders when seeds are to be obtained, but eat grassy tissue as well. A character of interest is found at the base of the wings in the males, where the overlapping parts are ridged and toughened to form a stridulating or musical apparatus of a very effective order. The best known among this type are the Katydids, which are often tree and shrub dwellers but do not differ markedly in other respects from the more lowly meadow inhabitants.

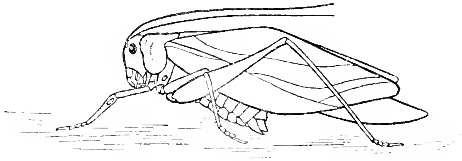

FIG. 18.—A long-horned grasshopper, *Microcentrum* sp.

The crickets are very diverse in their habits, both as to dwelling places and as to food; some confined to vegetable matter only, a few omnivorous and the tree crickets carnivorous. The latter are really the only injurious forms for, while they eat plant lice and similar creatures, they lay their eggs in the shoots of plants and sometimes cause their death; but this is an insignificant item as against their usefulness from the farmer's point of view.

On the whole, while the order *Orthoptera* contains many plant destroyers, the destruction is rarely total: that is, it is confined to defoliation which does not threaten the actual life of the plant, however completely it may destroy its value agriculturally.

In the order *Coleoptera* or beetles we have a very large number of species and a very great diversity of habits. They live under almost every conceivable condition where insect life is possible at all, and there is no organic matter, living or dead, which is not eaten by some Coleopteron in either the adult or larval stage. We may therefore expect to and do find enemies to all sorts of plant life and there is no part, from the tip of the finest rootlet to the topmost leaf, that is exempt.

Just how it happened that certain types of structure became associated with certain feeding habits makes a very interesting question on which there are widely divergent opinions; but for our purpose we can simply accept the fact that the general life habits of any beetle can be approximately stated from an examination of the feet, the antennæ or feelers and the general type of mouth. There are exceptions in every large group as the result of special adaptation, but for general purposes the test answers well.

We have a large series of species, most of them terrestrial but a few aquatic, in which the antennæ are slender, made up of usually eleven joints of similar form, and the feet are 5-jointed on all legs. All these are predatory in general habits, both as larvæ and adults, and none are characteristically enemies of plant life. There are some that eat plants, and a few have caused injury at times; but these are exceptional instances.

Coming next in the order of series are the Clavicorns in which the antennæ are thickened toward the tip so as to form a distinct enlargement or club: the feet, all of them with the same number of joints, though the number may be from three to five, none of them with the third joint lobed. By far the largest part of this series are scavengers, living in fermenting, dry or decaying animal and vegetable material of all kinds. A very few, comparatively, are predatory and yet a smaller number are feeders upon living vegetation; none of them in any very characteristic way nor so as to threaten the existence of the plant attacked; but still giving variety to the series.

These are followed by the *Serricornia*, in which the antennæ have the joints more or less trigonate, or

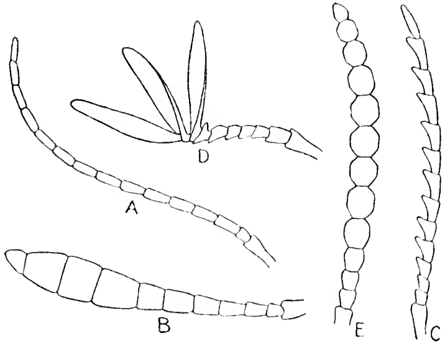


FIG. 19.—Antennal structure of *Coleoptera*. *a*, filiform; *b*, clavate; *c*, serrate; *d*, lamellate; *e*, moniliform.

saw-toothed, and the feet 5-jointed as a rule; always with the same number on all feet. Among these the vast majority are vegetable feeders, but this vegetation may be dead or alive, and most of the feeding is on woody tissue rather than foliage. The "click beetles," "snapping beetles" or *Elateridæ* are characteristic members of this series, and as wire-worms their larvæ are very often feeders on root tissue. The beetles gain their common names by the loose-jointed structure between the prothorax and the rest of the body, and their habit of snapping or springing up with a jerk when turned on their backs. The wire-worms gain their name from the tough leathery texture combined with a slender wormlike form and most of them feed underground, devouring the roots of many sorts of plants, severely injuring or actually destroying such as they attack. But there is also a large contingent that lives in woody tissue—nearly always dead tissue and quite generally such as is well advanced in decay. The insects can scarcely be called borers, because they are hardly fitted to make their way in sound wood; but in logs and stumps or even dead standing trunks they are often found in goodly numbers.

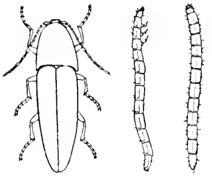

Fig. 20.—Click-beetle and wire-worm from side and top.

Typical wood-borers are found among the *Buprestidæ*, which are usually metallic, hard-shelled beetles, generally of good size, often with handsomely sculptured wing-covers. In the larval stage these are known as flat-headed borers or "hammer-heads" because, immediately behind the mouth structures the first thoracic segment is much enlarged and often chitinized, giving the appearance of a very broad, flattened head, followed by a long slender body in which all the joints are well marked. These borers work in the bast and sap-wood of the trunks and branches of trees and shrubs, making shallow galleries of more or less characteristic shape and sometimes enormous length. A single borer not over an inch and a quarter long, may make a gallery an eighth of an inch wide and over ten feet in length, leaving a trail of dead tissue that the tree in many cases cannot replace or mend.

If this trail is along or with the grain, not much harm is done; but in many cases it tends to a girdling or to a cutting across the grain that involves a large part of the circumference. And when there are several such borers at work in one tree, fatal results follow. I have seen entire orchards of pear trees and fields of blackberry killed by borers of this character.

Sometimes, the larva, instead of making a long narrow gallery, eats out an irregular chamber beneath

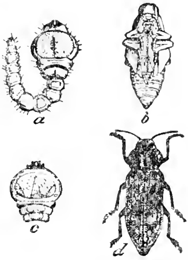


Fig. 21.—Flat-head apple borer: *a*, larva; *b*, pupa; *d*, adult.

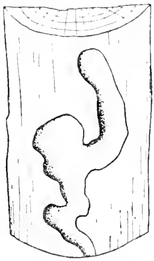

Fig. 22.—An irregular gallery made by a flat-head borer.

the bark, and that sort of injury is not nearly so serious, since it does not so much interrupt the circulation of sap. So there is quite a little difference of habit in the selection of the tree to be attacked. Some species never enter living trees and these are, perhaps, in the majority; but some never attack other than healthy tissue. As a rule, if trees are found infested by flat-headed borers, it can be assumed that they were already in rather poor condition before the entry; this new attack marking the first step in nature's attempt to get rid of an organism no longer aggressively healthy.

In those species that attack dead tissue only, some of which, like the cigarette beetle and death watch, are treated in Chapter X, we get an approach to the scavenger type; and yet the term scavenger seems scarcely a fitting one since the material attacked is not in a condition of either ferment or active decay.

In the "soldier beetles" and "fireflies," which by the form of their antennæ are members of this series,

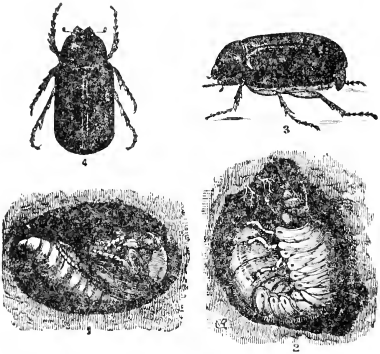

FIG. 23.—May beetle: 1, pupa in earthen cell; 2, larva or white grub; 3, 4, beetle from side and above.

we have a wide departure from the general feeding habit, most of them being predatory in the larval stage, and feeders among flowers, where they feed at all, as adults.

The series *Lamellicornia*, containing species with the feet 5-jointed and the antennæ terminated by a leaf-like club, includes vegetable feeders almost exclusively, in both larval and adult stages, and, in general, the feeding is upon live vegetation. There are the usual exceptions of course, but really very few in number. The common "May-beetle" or "June-bug" may be selected as a good type and this, as an adult, exemplifies the habits of the series in its voracious feeding. Most of the beetles of this series feed in the adult stage, and in almost all instances it is a direct straightforward devouring of growing tissue which does not endanger the life of the plant. In the larval stage the species are known as white-grubs and in this they are much more dangerous since they feed upon the roots, often destroying the smaller plants such as grasses, berries and the like. The step from living to dead vegetable matter is a very short one and so we find here also quite a number of feeders on dead or even decaying plants, which of course are not among the direct plant enemies.

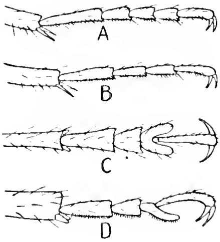


FIG. 24.—Tarsi of Coleoptera: *a*, normally 5-jointed; *b*, 4-jointed; *c*, 4-jointed with 3rd joint lobed; *d*, same from side: *c* & *d* always indicate a plant-feeder.

In that great series of Phytophaga, which contains the families *Chrysomelidæ* or plant beetles, and *Cerambycidæ* or long-horned beetles, we find all the tarsi or feet apparently 4-jointed, the third joint lobed or divided into distinct parts. This is a very characteristic structure and almost always indicates a leaf-feeder. Most of the adult beetles in the Chrysomelidæ feed very simply and openly on leaf tissue, devouring without plan or aim except to get enough. Occasionally we do get some characteristic bit of feeding like that of some flea beetles which eat little round holes, or make channels that render their work readily identifiable. The larvæ vary more in their habits and, while the vast majority are soft, naked, slug-like creatures, similar to those of the potato beetle, or only scantily clothed like those of the elm leaf beetle, there are some that are more slender, white, and worm-like, mining in stems, leaves or even roots, and making more or less characteristic galleries, channels or chambers. They may be only surface channels like those made on cucurbs by certain species of *Diabrotica*; they may be real borings like those made in root tissue by some flea beetles; or they may be mines in leaf tissue, like those made by some of the species of Hispids. It is rare that the attack of a Chrysomelid really threatens the life of a plant, though there are exceptions to this; the grape-vine root-worm for instance, and other root-feeders.

In the long-horned beetles, or *Cerambycidæ*, the adults do very little feeding; but the larvæ are borers in woody tissue or in stems of plants, differing from those of the Buprestids by being more cylindrical and with a less prominently dilated anterior portion. They are known as round-headed borers as distinguished from the flat-headed kind already described, and their galleries in section are nearly round instead of transversely oval. As a rule, also, they are more generally borers in heart-wood and do not make the irregular shallow galleries under bark that are so characteristic of the flat-headed types. There is no part of a tree that is exempt from their attacks: from the roots to the very tips of the twigs it may be infested, and they do not confine themselves to sick or dying trees either: a perfectly sound tree is just as likely to be attacked as any other and, indeed, some species are found in sound trees only. There are many interesting points connected with the development of these borers, the life period of some of them being drawn out enormously under unfavorable conditions. Thus, if a piece of infested timber is worked up into furniture, a larva which normally matures in two or three years may live for eight or ten years or even longer; and in some cases wainscoting has been found infested, several years after it has been in place, varnished and polished so as to forbid the idea that some misguided adult oviposited there after the boards

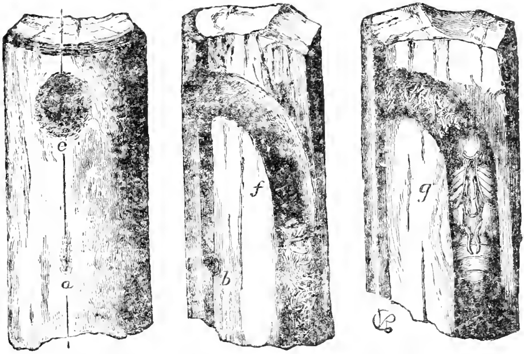


FIG. 25.—Round-head apple borer: *a*, puncture where egg is laid; *b*, same in section; *e*, hole from which beetle has issued; *f*, same in section; *g*, pupa.

were in position. Some species require the wood in a particular condition to secure their best development, and so a beetle, before laying its egg, may girdle the twig so as to interrupt the flow of sap and then oviposit above the girdled point. Other larvæ bore into live twigs and, when ready to transform to the pupal stage, cut through from the inside until only the bark and a mere shred of woody tissue remain. Then the burrow is securely plugged with sawdust and the larva retreats

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into its gallery, above the point of cincture, certain that the next high wind will bring it safely to the ground. Considering the enormous variety of species and the number of points attacked, it is surprising that the amount of injury caused is not much greater than it is. But, aside from the natural checks, the insects grow slowly in the larval stage and are rarely great eaters; the borings of some of them being surprisingly short, considering the size of the larva and the length of time it feeds; furthermore, the twig and branch borers in most cases produce only a more or less injudicious pruning, while the borings in the heart wood on a large tree do not necessarily threaten its existence. Still, these round-headed borers may be accounted among the more serious enemies of woody plants.

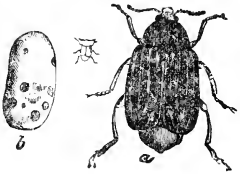


FIG. 26.— Bean-weevil, natural size and enlarged, and a much infested bean.

A little offshoot from the plant-feeding beetles are the *Bruchidæ*, commonly known as bean- and pea-weevils because the majority of them attack the seeds of plants belonging to the *Leguminosæ* or pod-bearing family. This includes not only the bean and pea of the garden, but such tree forms as the locusts, and almost every series has its own species of Bruchid that lives and comes to maturity in the seeds. The term weevil is not strictly applicable to these insects for, although the head is very small and pointed, it is not produced into a snout, and the body is unusually obese, the wing-covers squarely cut off behind and leaving a large area of abdomen exposed posteriorly.

Next comes a series known as the *Heteromera*, in which the anterior and middle feet have five joints but the posterior four joints only. It includes a great variety of species, many of them of sombre, uniform color, shunning the light, living in concealment and often or even generally feeding on dead or dry vegetable matter. Yet there are exceptions to this, as for instance the blister beetles which, in the larval stage, are semiparasitic, and as adults feed ravenously on vegetation. When they are feeders on living plants, however, it is as straight-forward devourers of leaf tissue that they appear, and they do not threaten the existence of the plant attacked, however much they may injure it for the farmer's purpose.

And now we get the *Rhynchophora* or snout beetles which, broadly speaking, include the bark beetles or Scolytids and with them some of the most dangerous enemies to plant life. Popularly most of these species are known as weevils and, so far as I am aware, all of them are plant feeders. And there is no part of the plant from root to tip that is not attacked; no stage from seed to pollen that is not eaten by them. They are among the oldest of the Coleoptera in the geologic record and have adapted themselves to life on vegetation under all sorts of conditions. The term snout beetles calls attention to one of the most prominent external structures—the elongated head drawn out into a beak of varying length, at the end of which the small mouth parts are situated. For feeding purposes these do not seem to be especially well designed, indeed in many species the mandibles are deciduous and are shed soon after the adult is developed; but for hiding and placing the eggs no better nor more practical tool can be imagined. For instance, almost every one that has gathered nuts has had the experience of finding some of them wormy, with absolutely no trace of an opening on the outside to show how that worm or grub ever got into it. If the grub is bred to maturity it will develop into a snout beetle with a very slender brown beak, from one half to three quarters of an inch in length or even longer. With this long snout the parent punctures the forming burr of the chestnut or husk of the other nuts, and into the very centre it runs its minute channel. It then turns, places an egg into the mouth of the opening so made and again turning, slowly and gradually forces the egg into place with the beak. The rapidly growing plant tissue effaces all trace of this puncture, and there we have

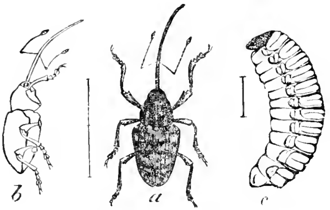


FIG. 27.—A nut-weevil: *Balaninus* sp.: *a*, from above; *b*, from side; *c*, larva.

our embyro grub already in place, almost before there is any differentiation between shell and kernel. It is interesting to note in this connection how carefully nature guards against the extinction of any of her creatures by a season of adverse conditions. A species dependent upon the hickory-nut for instance might, in case of a total failure of that crop for some one year, become locally exterminated if all specimens followed the same routine. But were we to put 100 grubs into confinement in fall, when nuts are ripe, and permit them to go underground to pupate, we would probably get not over sixty adults the spring following; and if we left our specimens undisturbed we would probably get thirty more the next year thereafter and the remainder the third year following. This seems to be rather a wide-spread provision for tiding insects over a bad season and, not only in the snout beetles but in many other groups, single-brooded species that pass the winter in the pupal stage, may lie over for one or even two years after the bulk of the brood has become adult.

By virtue of this provision for placing eggs, many of the snout-beetle larvæ are feeders in blossoms, fruits and seeds, and enormous damage is caused to trees and plants by limiting their seed bearing powers. When these fruits are of commercial importance like the plum, the horticulturist classes the "plum curculio" as a first class pest and a subject for investigation by the economic entomologist. If I mention once again the cotton-boll weevil, and cite as a further example of seed destruction the strawberry weevil, the danger of this sort of insect to plant life may be appreciated. It is of course the larva that does the injury, and curculio larvæ are all more or less grub-like in character; mostly white like the generality of internal feeders, and usually with a brown chitinous head furnished with well-developed jaws or manidbles.

Blossoms, fruits and seeds furnish only one article of diet for weevils and their larvæ: many bore into the stems of herbaceous plants, as the rhubarb weevil; others bore into wood tissue like the white pine weevil, and the latter, by killing off the leading shoots, frequently distorts a tree to such an extent as to make it commercially useless. A comparatively small number are external feeders on plant tissue like the clover-leaf beetle; a few make tubes or other cases out of the leaves on which they feed, and some cause galls or other enlargements. There is, therefore, scarcely a method of attack that is not represented among the snout beetles.

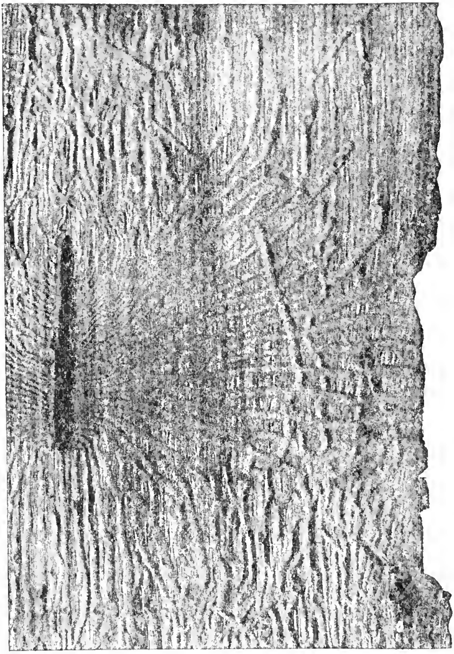

FIG. 28.—A piece of hickory bark, illustrating the work of *Scolytus 4-spinosus* and its larva.

The Scolytids or bark beetles deserve separate mention, as they are among the most dangerous of all tree enemies and the greatest destroyers of wood tissue, living or dead. The name bark beetle is a misnomer for many of the species, which never bore into or under bark at all; but it applies well to a very large number that make characteristic borings or galleries beneath the bark or in the sap-wood. In forms of which the common fruit bark beetle may be considered typical, the adult bores a longitudinal channel in the sap-wood and lays eggs on each side in little notches cut for that purpose. These beetles are all more or less cylindrical, slender and elongate, with a very short or scarcely perceptible snout and well-developed jaws or mandibles. The larvæ that hatch from the large white eggs are of the usual grub-shape, white with brownish head, and each larva makes its burrow at right angles to the main gallery, diverging a little upward or downward as it increases in size so as to avoid its neighbors, and making a pattern so distinctive that the species may be recognized by its borings alone. Quite usually beetles of this character attack trees that are a little weakened or unhealthy, but some take to perfectly sound trees and cause serious trouble. Other species bore into the heart wood, their galleries being cylindrical, often blackened or discolored, and these are sometimes called shot-hole borers.

No kind of tree is exempt from the attacks of such beetles, and thousands of acres of forest lands in all sections of the United States are annually destroyed by them. And much timber is rendered useless or lessened in value by the borings which disfigure or weaken it, where the life of the tree itself is not threatened. In trunk, in twig and even in the roots these Scolytid borers are found, and our knowledge of them still leaves much to be desired. Only a small proportion of our species are actually known, and their classification at present is merely tentative. They are receiving more attention now than ever before, and they merit more attention than they are receiving.

Altogether, the *Coleoptera*, among the dominant orders, furnish a very large number of destroyers of plant tissue living and dead, and many that may be ranked as destroyers of plant life.

The order *Lepidoptera* includes the butterflies and moths and their larvæ are known as caterpillars. Caterpillars with few exceptions feed on plant tissue, hence, as a whole, the members of the order may be considered as enemies of plant life. Mainly they are open and above-board enemies: direct feeders upon the leaf tissue, without modification or concealment. Such feeding in itself does not endanger plant life except in cases where there is an unusual number of caterpillars or the plant is one that will not survive defoliation; therefore the number of species dangerous to plant life in this way, is not really very great. There are such species, of course, for in the State of Massachusetts there are hundreds of conifers dead as the result of defoliation from gypsy moth, and in general, any species that can completely strip a tree may cause its death.

A comparatively small number of Lepidopterous larvæ are borers in woody tissue, and these are mainly members of the families *Sesiidæ, Cossidæ* and *Hepialidæ*: all Tineites under the modern classification. The *Sesiids* are small clear-winged moths resembling wasps in appearance, and their larvæ bore into trees and in the stems of herbaceous plants. The peach tree borers are types of the former, working under the bark at the surface of the ground and often causing the death of young trees; the squash borer is a type of the latter, boring into the stem of the plant at almost any point; but most often at the base. Both types frequently cause the death of the plants attacked; but there are others, like those attacking the trunks and branches of oak and maple, that may infest their host for years without causing obvious harm. Not only the tissue above ground is attacked, for one species

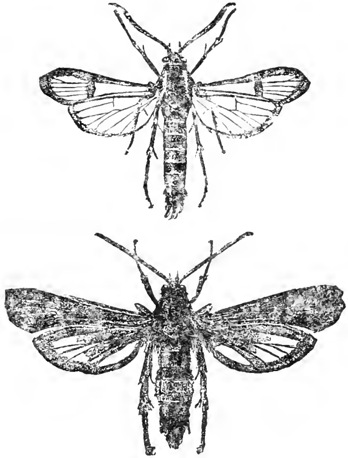

FIG. 29.—The peach borer, *Sanninoidea exitiosa*; male above, female below.

at least occurs on the roots of grape, and others are underground on oak.

The *Cossids* are much larger forms and correspondingly more dangerous. The European *Zeuzera pyrina* or wood-leopard moth, which has been introduced into the eastern United States, frequently girdles young trees and often weakens the branches of older ones to such an extent as to make them easy victims to wind storms. Some of our own carpenter worms make simpler borings; but owing to their methods of work, leave sore spots that often form points of entrance for germs of decay. Thousands of oak trees in the eastern United States are "doated" as the result

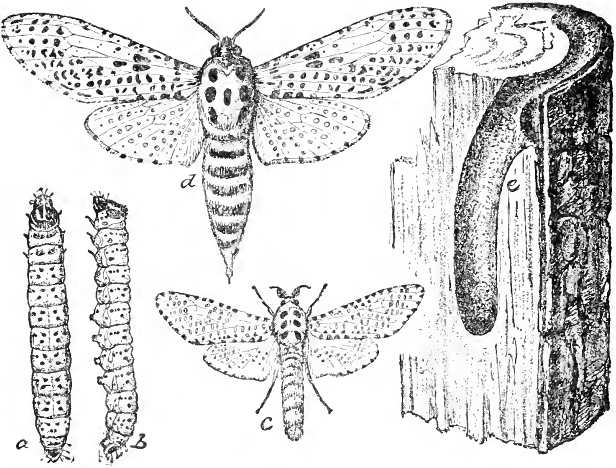


FIG. 30.—Wood-leopard moth, *Zeuzera pyrina: a, b*, larva; *c*, male; *d*, female moth; *e*, larva burrow.

of the work of these borers; stunted in growth and useless as timber. Fortunately the number of species is small and very few of them are at all numerous in specimens.

The *Hepialids* are very ancient in type and they are few in number of species and specimens. The larvæ are large and make large channels in roots and trunks; but I have never known of any serious injury done by them.

There are many others among the Tineid families that are borers in herbaceous and shrubby plants and some cause galls or other abnormal swellings in the infested stems; and there are many others that mine or bore in leaves, causing a great variety of disfiguring injury, but rarely anything that threatens the life of the plant itself. Many of these little caterpillars and a few larger species make cases or covers of the most diverse character, and others live in shelters spun by the members of one brood from a single laying of eggs. Some live altogether in silken tubes spun by the caterpillars, and of these some feed underground on the roots of corn and other plants. Quite a number feed inside of fruits, like the Codling moth of the apple or the berry moth of the grape, and a few get into seeds like the Angoumois grain moth.

We have, then, among the *Lepidoptera*, a very large number of feeders on vegetable tissue, that destroy portions of the plant without endangering its life, and a comparatively few that are really dangerous to the existence of the organism attacked, however much it may be injured from an economic standpoint.

The order *Hymenoptera* contains a large number of species of very great interest: some of them vitally important to the continuation of plant life, and on the contrary a few that are destructive to it: but it is interesting to note that among the bees which have been shown in the preceding chapter to be among the greatest benefactors of plants, we should also find an element of danger. Plants suffer from "blights," "rusts," "scabs" and a variety of other diseases and, recently, plant pathologists have charged that bees in their visits to flowers engaged in the beneficial work of pollination, at the same time carried also the germs of fire-blight and similar diseases, introducing them into the sensitive tissues of the blossom. It is an old story, of course, that disease organisms frequently find entrance through wounds made by insects; but that is merely putting the insects on a par with other causes that produce abrasions, cuts or bruises: this is a different matter, the insect being charged as the active transmitter, much as a fly carries typhoid germs to the human organism.

Direct plant feeders are found among the *Hymenoptera* in the *Sessiliventres*,—"saw-flies" and "horn-tails,"—which derive their technical name from the fact that the abdomen is joined to the thorax for its full width and is thus sessile, while in the majority of the species in this order it is stalked or pedunculate, attached at a narrow point only. The saw-flies are somewhat clumsy in appearance and more sluggish than the other *Hymenoptera*, the body rather uniform in size from end to end, the wings large, with many complete cells, and folded over the back when at rest. They derive their common name from the fact that the ovipositor is made up of parallel blades variously toothed at the edge, by means of which the female cuts a slit or pocket into a leaf, stem or twig, for the reception of an egg. The larvæ that hatch from these eggs are caterpillar-like in appearance but have five pairs of abdominal prolegs instead of four or less, as is the case in the true caterpillars. They are mostly feeders on foliage, like the currant worm, and they sometimes appear in enormous numbers; but they do not often threaten the life of the plant. Some of them only scrape the surface of the leaves like the pear slug, while others eat characteristic holes in them like the blackberry saw-fly. A considerable number are gall-makers, largely on willow, the excrescences being quite characteristic.

The "horn-tails" have the ovipositor modified into an augur-like process for making holes in plant tissue, and the larvæ are mostly borers: some in wood, most

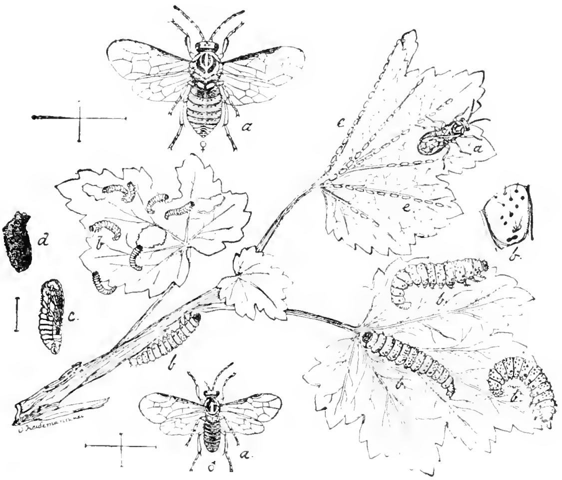

FIG. 31.—The currant worm: *a*, adults; *b*, larvæ in various stages of development; *c*, pupa; *e*, eggs along veins on leaf.

of them in shrubs or grasses. These very often threaten the life of the plant attacked, especially when wheat or other grasses are infested. But on the whole the number of these boring species is small, nor are they often numerous in examples.

A very characteristic set of species is found in the "gall-wasps" or Cynipids now ranked as a superfamily under the term *Cynipoidea*. These gall-wasps produce in the plants attacked abnormal swellings or growths known as galls, which are constant for every species and differ as the species differ. Thus for those forms whose life history is known, the gall is as good an index to its kind as a specimen of the wasp. And the remarkable point is, that the gall is purely a production of the plant and the insect has, apparently, nothing at all to do with it. The female lays the egg and in due time a minute larva hatches. Immediately there begins to develop around this larva an abnormal growth centered by a smooth cell in which the larva lies, a white helpless grub, feeding upon the exudations that come from the inner side of the cell. The relation between the irritation set up by the minute larva just out of the egg and the remarkably complicated structure of plant cells built up around it has never been clearly elucidated and offers an excellent opportunity for research. Some galls are spongy in texture, some are solid; some are filled with radiating fibres extending from the central cell to the covering sphere; some are no larger than necessary to accommodate the insect and yet others are huge bladder-like affairs, out of all proportion to the size of the larva. Some galls are on leaves, some on twigs and branches and a few are on roots. On the roots and stems the growths are often corky or woody, and sometimes mere enlargements of the normal growth. More generally the galls are unicellular, *i.e.*, they have only a single central cell containing one larva; but very often also they are multicellular, a large growth containing many larval cells which, in turn, may be very regularly or very irregularly disposed in the larger mass.

These gall-wasps have a number of very interesting features. Some of them appear, year after year, males and females, without variation; always making the same kind of gall. Others appear in spring from over-wintered galls, normal males and females: the latter lay eggs, galls appear, but from them only females make their appearance; these in turn lay eggs and from their galls males and females appear again the year following. This is termed an "alternation of generations" and so long as the galls are similar and the fe-

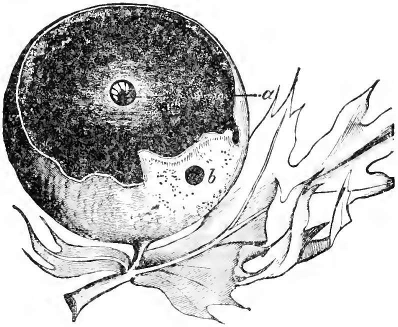


FIG. 32.—An oak gall, made by *Cynips q-spongifica*; *a*, showing the larva in its cell; *b*, exit hole of adult.

males are similar, no confusion is caused. But it sometimes happens that the summer generation is very different in appearance from the hibernating form, while the gall itself is different and on a different kind of tree, so that there appears to be no sort of connection between them until the life history has been completely followed out—no light task in species of this character. For some species no males have ever been found and, so far as we know, these are maintained by parthenogenetic females alone.

It also happens sometimes that a normal constituent of plant tissue, like tannin, is greatly intensified in the gall structure which may contain many times more tannic acid than any other part of the tree. The galls, therefore, become of commercial value and in some localities the oak forests yield a considerable revenue from this source.

Few Cynipid galls are really injurious to the plants on which they appear. Those on the leaves are never so; those on twigs are rarely so; those on the larger branches sometimes cause a choking and sometimes a weakening that results in a fracture under strain; but frequently a badly galled branch will in its development split off and shed the old galls. Root galls sometimes threaten the life of a plant; but most of the fatal galls found on trees, shrubs, and vines are due to other causes.

In the *Diptera* we have plant feeders in great variety, and many of them endanger the life of the plants attacked; but they have a decided preference for soft tissues and there are no borers in solid, living wood.

Among the long-legged, mosquito-like species with long antennæ, the crane-flies have larvæ that live underground and feed on the plant roots. They are sometimes called "wire-worms" because of their long slender form, and "leather-jackets" because of their texture. They differ from the beetle larvæ that are also called wire-worms, by the more cylindric shape, the more pointed head, and absence of legs. Their feeding on roots is sometimes extensive enough to cause the death of the plant attacked. The crane-flies are the largest of the long-legged forms, some of them measuring with legs extended nearly three inches.

The gall-midges are at the other extreme and include very small species with very long, often prettily beaded antennæ. Their larvæ are little footless grubs, peculiar by having a single chitinous rod or anchor-like structure known as a breast-bone, which serves to scrape the plant tissue on which the creature feeds. These gall-midges or *Cecidomyiids* attack a great variety of plants at all sorts of points, and cause a great

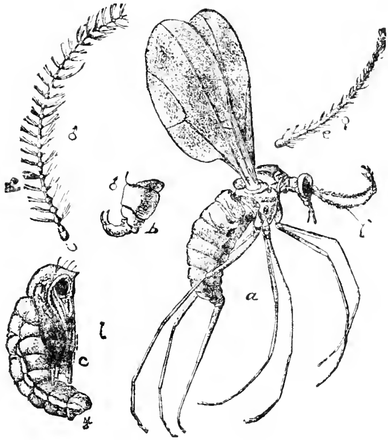

FIG. 33.—The pear midge, *Diplosis pyrivora: a*, female adult; *c*, pupa; other references to structural details.

variety of deformations that are commonly known as galls, although they differ totally in character from the galls caused by the Cynipids. For instance, the pear midge lays its eggs in the pear blossom; the larvæ enter the seed capsule of the fruit and the latter becomes somewhat abnormal in shape so that to the practised eye the galling is perceptible. The Hessian fly lays its egg in the sheath of the wheat leaf near

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the ground; the larva starts its feeding there and causes an injury which the plant, in its efforts to repair, marks by an enlargement. A midge lays its eggs in the tip of a willow shoot, the larvæ feed at the base of the forming leaves and the plant becomes crippled, producing a cabbage-like head instead of a shoot with developed foliage. And so we have every gradation from a feeding without any perceptible enlargement or swelling at all, to a well-formed abnormity formed by a crippling of the natural growth, and not a distinctly separate structure, unrelated to normal growth. There are other types of midge-galls, like those on the grape, which are mere fleshy swellings of the normal tissue, and sometimes more characteristic enlargements of infested twigs; but generally no separable galls.

As to the actual injury caused, that varies enormously. Many of the midge-galls cause no real or permanent injury whatever to the plant attacked. Others destroy either the plant or the seed beyond all chance of recovery. These midges are to be accounted among the most serious plant enemies, although soft herbaceous plants and grasses are more apt to suffer; very few of them occurring in genuinely woody tissue.

Among the Muscid flies resembling in general type and appearance the house-flies, the Anthomyiids are the most troublesome and dangerous. They attack a very great variety of plants and may be miners in the thick leafed forms like beets, or feeders in roots like those of the radish, cabbage or onion. And these root maggots are very generally fatal to the plant attacked, so that their rank as destroyers is high. The maggots themselves differ very little from the other Muscid larvæ; in fact not at all to ordinary view, and they gain their food in the same way by scraping and disintegrating the tissue and then absorbing the liquid mess. There is, in consequence, nearly always an appearance of decay associated with the work of such maggots, and that appearance is very real in cases where the wounded surface gives entrance to soft rots of various sorts. As for the leaf miners, their work is not so destructive in character, although naturally every injury that impairs the usefulness of the foliage to the plant, reacts upon the entire organism to some extent.

There are other maggot-like larvæ that work in plant or fruit tissue such as the apple maggot, the orange fruit fly and a considerable number of other fruit flies which, while they seriously affect the commercial value of the product, do absolutely no injury to the plant, since neither the seed nor the tree itself is affected. Only the pulpy covering to the seed is harmed and that is of no importance at all to the plant however much it may be to man.

We have thus reviewed very briefly the various orders of insects, and have called attention very cursorily to the kind of injury which is caused by them. From the time it appears above ground to the period of maturity, almost every species of plant serves as food for insects; and if it survives their various assaults and reproduces its kind, its decay and return to the inorganic constituents from which it made its growth is hastened by yet other species. And that applies as much to the forest giant, aged hundreds of years, as to the humble cabbage plant that runs its course in a single season.

## CHAPTER IV

### THEIR RELATION TO EACH OTHER

It has been brought out, directly and incidentally, that insects are among the most prolific animals. If all the feeders on vegetable life were allowed to develop absolutely without check during two successive years, the first of them would see every green thing swept from the face of the earth, and the second would destroy all possibility of the future recurrence of fully 90 per cent. of all the existing plants. And if during the same period all forms feeding upon vertebrate life were allowed to develop in the same way, our globe would be a practically uninhabited and uninhabitable desert.

But the very fact that they are so remarkably fecund is an indication that they have many dangers to contend with and many difficulties to surmount before reaching the adult or reproductive stage. Under normal conditions and in the long run, one pair of moths, producing say 500 eggs, are represented next year by another pair of the same species, and no more: that is, out of 500 eggs, producing 500 caterpillars, 498 are destroyed in some way. Naturally this varies from year to year to some extent, favorable conditions permitting an increase one year and causing a decrease at some other period. And, equally of course, while some broods may be completely destroyed, others may all come to maturity.

Now the very fact that an insect exists at all, is proof that it is adjusted to its surroundings, including its parasitic and predatory enemies and all the other natural checks. And when it occurs as an abundant species it means that this abundance is normal, and that the natural adjustments are such as to maintain that abundance in relation to its food unless man interferes, and the results of such interference will be the subject of further discussion, later. The important point is that a species abundant in number of specimens has become so in spite of the combination of all its natural checks and, conditions remaining equal, will maintain itself in the same ratio, just as a rare species barely maintains itself against the combination opposing it. It happens again and again that a common species becomes more than usually abundant, and it occurs occasionally that a species normally rare escapes from its control and makes its mark as an injurious form. But even without human interference this rights itself in a season or two: the common species may even be reduced for a time to less than its usual numbers, while the rare species drops back out of sight of all but the collector. The checks or natural enemies of neither form ever increase sufficiently under normal conditions to do more than restore the original ratio.

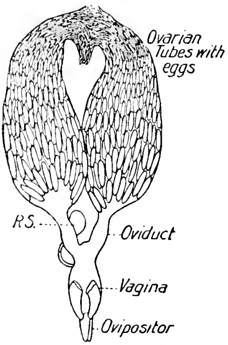

FIG. 34.—Ovaries of a bee showing the different parts.

What then are these checks that prevent with such absolute effect any undue increase of a species despite enormous reproductive powers? They are really very numerous and of decidedly unequal effect on the different forms. We have weather, disease, insectivorous animals of many species, birds and, last but by no means least, in the war of insect upon insect, the predatory and parasitic forms. It was almost inevitable that in the course of development some originally plant-feeding insect would find itself in position to get its plant juices at second hand, so that, instead of feeding upon plant tissue directly, it fed upon its next neighbor and got the same material indirectly. We have, even now, examples in *Hemiptera* and *Coleoptera* of species that feed upon vegetable tissue and also upon other insects when they get in the way; or of species which, while normally predatory, occasionally feed upon vegetation. In the *Hemiptera* I know of examples of this kind in the *Pentatomidæ* and in *Coleoptera* they occur in the *Carabidæ* and *Coccinellidæ*. And the step from predatory to parasitic habits is an easy one, albeit a much greater specialization. Insect feeders upon vegetable life were first developed; predatory forms came very soon afterward and occur in almost if not quite all orders; parasitism on other insects came much later, and is best developed in the highest and most specialized orders, being practically non-existent in the lower or primitive types. Parasites on higher animals, such as the biting and sucking lice which occur in the *Neuroptera* and *Hemiptera*, are not in any way comparable with the insect parasites that occur in the *Hymenoptera* and *Diptera*, to which highly specialized and most recently developed orders the great majority of all the parasites on insect life belong. There are few true parasites in any other of the orders.

Among the *Thysanura* we have no parasites and no predatory forms. In the *Neuroptera* we have many decidedly predatory forms and the beginnings of parasitism. The *Neuroptera* as limited in Chapter I, consists of a number of remnants of earlier types, agreeing only in the fact that the wings have numerous longitudinal and transverse veins, breaking them up into many small areas so as to appear more or less netted. But in the detailing of habits and suggesting lines of descent, further subdivision is convenient.

Thus the *Ephemerida* or May-flies contain neither parasitic nor predatory forms. In the larval or early stages they live in the muddy bottom of streams, feed on the organic life contained in this material and, in the adult stage, do not feed at all. Yet it is here that the highest orders get their start and in them predatory and parasitic types are numerous.

In the *Plecoptera* or stone-flies we have a similar record except that the mouth structures in all stages are much better developed. Here the larval stages are passed under submerged stones, usually in running streams, and the food consists of such floating organic material as is carried in. The adults in spite of their rather well-developed mouth organs have not been observed feeding.

The *Mallophaga* or biting lice are animal parasites and are dealt with in Chapter VII, and the *Corrodentia* or book- and bark-lice are feeders on dry or dead organic matter; not really scavengers, but nevertheless removers of dead material.

The order *Isoptera*, containing the Termites or white ants, is interesting from its communal life and will be referred to again; but it depends entirely upon vegetable matter for its subsistence and mainly upon dead tissue.

The order *Platyptera* is the first of the Neuropterous types to contain predatory forms and, while it is aquatic like the *Plecoptera*, has the metamorphosis complete and is altogether much better developed, albeit the adults are loose-jointed and flabby enough, when handled.

The larvæ have the jaws and other mouth parts well developed and feed upon other soft-bodied aquatic forms. They assist in checking the increase of the May-flies and stone-flies, and are themselves hunted by fish, which keep them down to normal numbers.

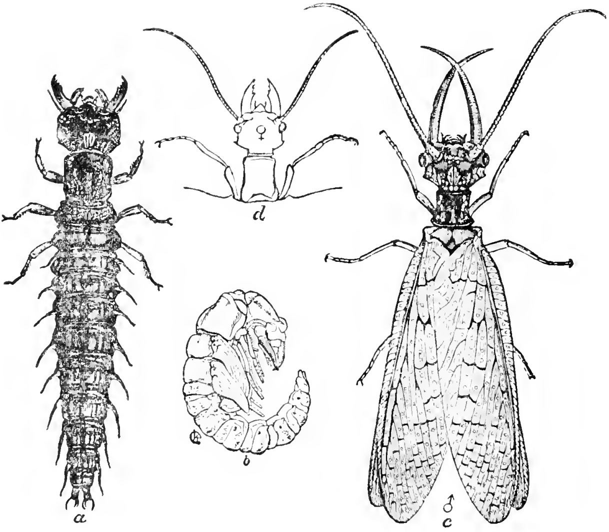


FIG 35.—The "hellgrammite" or "Dobson": *a*, larva; *b*, pupa; *c*, male adult; *d*, head of female.

The order *Neuroptera*, strictly speaking, contains only predatory forms and the beginning of parasitic habits. With few exceptions the species are terrestrial. The families *Coniopterygidæ*, *Chrysopidæ*, *Hemerobiidæ* and *Myrmeleonidæ*, are rather similar in the larval stage; the body being more or less ovate, set with lateral tubercles giving rise to groups of bristles, while the mandibles are long, slender and pointed, peculiar in being grooved on the inner side so that the body juices of the prey may run down through them into the mouth cavity. The *Chrysopidæ* are known as Aphis-lions, and when they capture a plant louse it is held up, impaled on the mandibles, until the juices are all

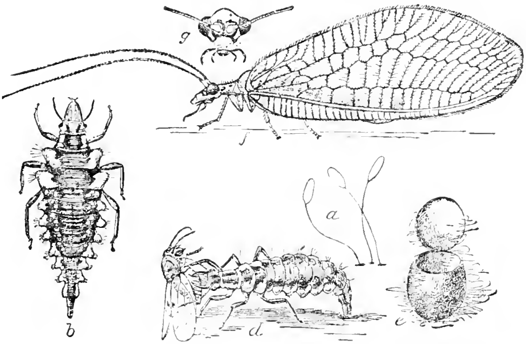


FIG. 36.—A lace-wing fly, *Chrysopa oculata*: *a*, eggs on stalks; *b*, larva; *d*, same feeding on pear psylla; *e*, the cocoon from which *f*, the adult, has escaped.

absorbed; then the dry carcass is thrown away. The *Myrmeleonidæ* or ant-lions build a pit in the sand to entrap any unwary insect that may come along, and anything that does come is seized in the same way and exhausted, the empty shell being thrown out later. Not all ant-lions build pits and not all the members of the families named agree in all respects with the general statements as to larval form and characters; but for the majority of the species that come under observation they are correct.

The *Raphidiidæ* are very curious creatures peculiar to the Pacific Coast, in which the head and prothorax of the adult are greatly elongated and it, as well as the slender elongated larva, is predatory. In the preceding families, while the larvæ are voracious feeders, the adults feed little or not at all.

The *Mantispidæ* are similar to the *Raphidiidæ* in the elongation of the prothorax; but the head is much shorter and the fore legs are enormously developed for grasping, this series being also predatory in the adult stage. But the interesting feature is that we find in the larva the first tendency toward parasitism and the specializations accompanying it. The eggs are laid on stalks like those of the Aphis-lions, but the resulting young live for months without food, until the egg sacs of certain *Lycosid* spiders have been formed. The lucky larva that finds such a sac bites its way through the covering and feeds upon the contents. As it feeds and grows it loses its large head and long legs, and becomes helpless except to feed upon the surrounding material which serves to bring it to maturity. While in a general way these insects are said to be parasitic in the egg sacs of spiders yet this is not really a true parasitism at all; it is simply a feeding upon the eggs and young spiders as any predatory species might feed upon them, the only difference being that here the larva makes itself at home and does its feeding gradually, so as to secure enough to reach maturity.

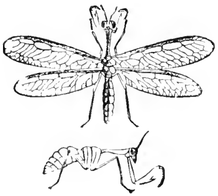

Fig. 37. — *Mantispa* species from above and in outline from side.

The order *Mecoptera* is a curious one, only a few genera and species remaining as representatives in our fauna. All of them are feeders on animal matter and most of them are predatory in all stages. The best known forms are the scorpion flies, so called from the curious anal appendages of the male, which bear a remote resemblance to a scorpion tail without its terminal sting. The larvæ, which are somewhat caterpillar-like, live under ground and prefer rather damp places. There are not enough of the insects to make them of any importance as checks to anything in particular,

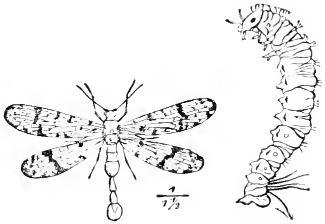


FIG. 38.—A Panorpa or scorpion fly and its larva.

and as they feed rather indiscriminately on soft-bodied insects, chiefly flies, they are of no economic value. It is probable that this order represents the type from which the *Diptera* and *Hymenoptera* were derived.

The caddice flies or *Trichoptera* are aquatic in the larval stages and as aerial adults do not feed at all. As larvæ they derive their name from their habit of making cases or "caddices" of various shapes from little sticks or stones closely fitted and held together with silk. Some of the species are feeders upon vegetable matter, others appear to be predatory, or feeders upon animal matter at least. They are very numerous in specimens and species, but naturally do not influence any terrestrial forms. The adults have the wings covered with fine hair and some of the small forms resemble Tineid moths so closely that they are confused with them. It is believed, indeed, that this is the direct ancestral form of the *Lepidoptera*.

And now comes the order *Odonata*, containing the dragon flies, large and small and all of them predatory in habit in all stages. As larvæ they are aquatic, living in ponds, streams or even the more permanent pools

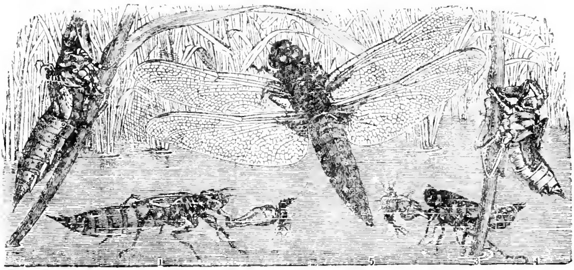

FIG. 39.—Dragon fly and its development: larva and pupa feeding at 1 and 3; 2, nymph ready to change; 4, pupa skin from which 5, the adult, has emerged.

and puddles; some of them active, moving about freely among the vegetation, others sluggish, lying in the soft bottom mud or under stones or other shelter, waiting for things to come their way. They are peculiarly adapted by their elongated hinged under lip, or labium, to reach such small creatures as fate may send within half an inch of them and, with a little forward jerk of the body and a rapid extension of the armed labium, the prey is seized. This prey varies in character according to the habits of the larvæ. Some of the more active forms destroy a large number of mosquito wrigglers and display surprising skill in capturing them. Others take in anything that comes along, be it insect, crustacean, or even small pollywog or fish. They have no aversion to their own kind and will eat each other if food is scarce or not easily obtainable. As for the adults, anything that comes within their range will answer as prey; but in general small flies are the most abundant victims. The common name "mosquito hawk" indicates one common article of food, and there is no doubt that a very large number of specimens is eaten. In some cases the mosquito pest may even be materially lessened by them during the period of adult flight; but they scarcely rank among the really controlling checks because they are active only during the day while the mosquitoes prefer the night for their flight; and the dragons prefer the open sunlit area around ponds or along streams, while those mosquitoes that fly at all during the day prefer sheltered, shaded and darkened places. Most of the dragon flies are simply general predatory feeders on any soft-bodied insects which they can overtake, rather than specific enemies of any one form.

In the order *Hemiptera* there are no parasites on insect life. The lice, parasitic on vertebrate animals, are elsewhere considered, and nowhere else do we find, in this order, any approach to true parasitism. Of predatory forms there are a large number; indeed among the aquatic species the majority are predatory, feeding on other water insects and even fish. Among these the little *Corisidæ* and *Notonectidæ*, water-boatmen and back-swimmers, are especially vicious and active, easily forming a very notable factor in the control of aquatic insect life.

Among the terrestrial forms the entire series *Homoptera* lacks predatory types; in the *Heteroptera* we find that modification of habit which is elsewhere referred to—a tendency to get plant juices at second hand, by sucking the juices of such soft-bodied larvæ as have just fed upon plant tissue. This is found in quite a large number of the families, making a con-

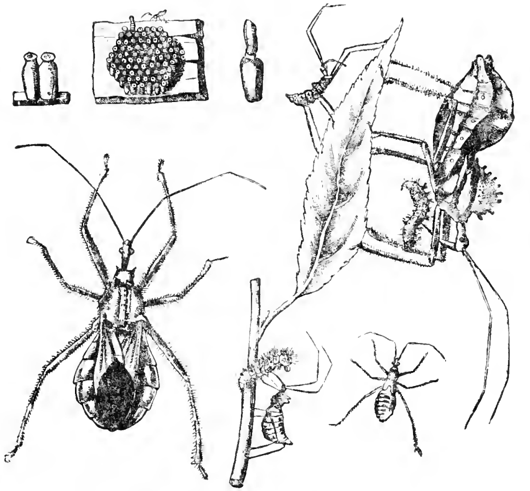

FIG. 40.—The wheel-bug, Prionidus cristatus, in all its stages.

siderable series of species that feed indifferently on plant or soft insect tissue. But there is also a large number of species with short stiff beaks and small narrow heads that are distinctly and exclusively predatory. These are the *Reduviidæ* commonly known as "pirate" or "assassin bugs" from their habit of stabbing or piercing the specimens upon which they feed.

These bugs are of considerable importance as checks to certain plant feeders and as they feed in the same way throughout their life, each individual accounts for a notable number of victims. Their weak point is the limited power of reproduction. Most of them lay only a small number of eggs and have only a single or at most two broods during the season. As a control factor, therefore, they lack flexibility and do not rise to any sudden increase in the plant feeders. There is a common species that in New Jersey feeds on the larvæ of the elm-leaf beetle, and each season is busily engaged on the infested trees in fair numbers. In years when the beetle is not abundant the marks of its feeding are quite conspicuous; but in a season when the beetle is unusually plentiful and destructive, the bugs are present in almost exactly the same numbers and their work is absolutely unnoticeable when effectiveness is most urgently needed, nor does there seem to be any considerable increase during the season following such an abundance. This same feature exists with most of the species known to me and limits their usefulness to very narrow bounds; they constitute one check which is almost a fixed quantity and to which the host insects are adapted.

The order *Orthoptera*, including roaches, grasshoppers, locusts, crickets and the like, contains no true parasites and but few predatory forms. Some of the roaches are omnivorous and pick up occasional specimens of insects and animal matter; but they can scarcely be ranked as important checks to any other species. And so the Mantids or soothsayers are voracious feeders, preying upon almost any sort of insects which they can secure; but they are few in number both as to species and specimens, while their food is so various that they are not of importance in the life cycle of any one kind. Crickets there are of many sorts, and some of these are general feeders, eating each other as freely as they do vegetation and other things. The tree-crickets are more definitely predatory in habits and feed largely upon plant lice; but they also are too few and too slow in reproducing to be able to exert a very important influence on the increase of their prey. Furthermore, they are limited as to the places which they inhabit, and no field crops of any sort harbor them.

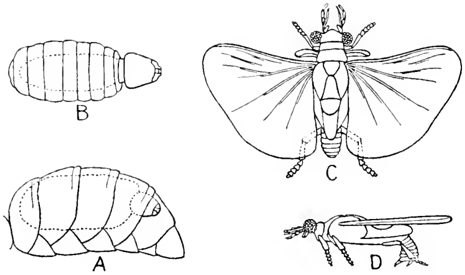


FIG. 41.—Stylops and its development: *a*, female in body of bee; *b*, same in outline; *c*, *d*, male from above and side.

In the order *Coleoptera* or beetles we have few truly parasitic forms. We may for the present consider the family *Stylopidæ* as true *Coleoptera* and these are found in the abdomen of various insects, chiefly bees and wasps although some *Hemiptera* and perhaps other orders are also infested. But they are so very rare that they exert little influence on the numbers of the species which they infest. Their life history and complicated metamorphoses are extremely interesting, the female being wingless and living in the abdominal cavity of its host, with the head projecting between the segments. The young are minute, active creatures like those of the blister beetles, and run about freely until they find some suitable host in which their future development may be continued. Then they lose their feet and prominent jaws, becoming grub-like and inactive as the necessity for seeking food is removed.

The blister beetles or *Meloidæ* are semiparasitic in habit and are quite numerous in specimens and species. Some of them live in the egg-pods of grasshoppers and others in the nests of digger bees, chiefly *Andrenidæ*, feeding on the food stored by their hosts and, incidentally, devouring the egg or young larva of the bee. These blister beetles will be referred to again in their relation to man, but in their relation to the insects upon which the larvæ feed they rank as most effective checks. The female beetle lays her eggs on flowers or on the ground as the case may be, and the resulting larvæ are active creatures with long legs and large jaws known as "triungulins." These are able to go for long periods without food and they seek either a grasshopper egg-pod or some plant or flower frequented by bees, as the need may be. The forms that hunt egg-pods, when they succeed in finding one, immediately begin to feed. The forms that wait for bees attach themselves to almost any hairy insect that comes along and the lucky specimen that gets upon a bee of the right kind is carried by it into its burrow. When the bee with its burden of pollen plus the parasite gets into the cell which it is filling with food for its larva, the triungulin slips off, devours the egg of its host as soon as laid, and that suffices to bring it to the end of the first stage. From this point the changes in both kinds of larvæ are similar. They are in direct contact with abundant food, the legs and large jaws are useless and they enter what is known as the "Carabidoid" stage in which they resemble the larvæ of ground beetles. Continued good feeding results in a further reduction of parts and the third instar is even more grub-like and therefore termed the "Scarabidoid" stage, during which it exhausts its food supply,—either the egg-pod or the stored material in the

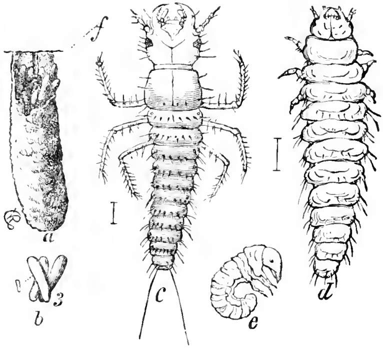


FIG. 42.—Development of a blister beetle: *a*, grasshopper egg pod with triungulin at *f*; *b*, a few grasshopper eggs; *c*, triungulin; *d*, carabidoid larva; *e*, scarabidoid larva.

bee cell. Then the outer skin hardens, the larva loses shape and enters the coarctate stage in which it lies dormant until the period when the adult is due to appear. When this comes, the hardened larval skin is shed and the true pupa, of the ordinary beetle type, appears. When the proper hour arrives, as if at the striking of a clock, the transformation to the adult is completed and the blister beetles emerge, ready to feed and propagate. And now the story changes, for while we can have only words of praise for those larvæ that feed on grasshopper eggs, the adult beetles almost without exception are devourers of plant tissue. Their habit of coming to maturity at about the same time brings clouds of them upon their food plants at once, and gardens and certain truck crops suffer. It becomes a question then, whether the insects are economically more useful as destroyers of grasshoppers or more destructive as feeders on crops. As to the species feeding in the nests of bees, they are without question economically injurious in all stages.

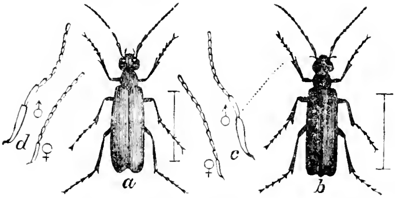


FIG. 43.—Two common blister beetles: *a*, *Macrobasis unicolor*; *b*, *Epicauta pennsylvanica*.

But there can be no doubt either that in regions where grasshoppers are very abundant, as they are in the Rocky Mountain and some of the southwestern areas of the United States, these blister beetles are a most important check and one that has a large amount of flexibility in effectiveness despite the fact that there is only one annual brood. This is obtained by the large number of eggs laid by the female, which in some species runs into the thousands. The adults make no attempt to place these near egg-pods, but only on ground where such pods are likely to occur. It is up to the young larva to find its own hotel accommodations or starve to death. When grasshoppers have been scarce and pods are widely scattered, a very large percentage of the triungulins never get beyond that stage; but when there has been an abundance of hoppers and egg-pods are numerous, matters are easier for the enemy and a larger percentage secures food. In this way it happens that after a season of grasshopper abundance a season of blister beetle abundance is almost certain to follow, and any abnormal increase of the former is almost sure to be checked by the corresponding increase of the latter.

A very material change is introduced by the migrating habit of some of the host species. Blister beetles are not great travellers, while a grasshopper swarm may fly for hundreds of miles, clear out of the faunal range of their check. But in such instances, while they may have a year or two of unusual freedom for development, they become in time victims of the unfavorable climatic conditions in their new surroundings and are crowded back into their natural domains, under the control of their normal enemies.

While, in a way, it is correct to refer to these beetles as parasitic, they are not really more so than the Mantispids that feed in spider egg-sacs, and in the case of those feeding in the cells of bees they are even less so. For here the egg or young larva of the bee is only eaten to remove the owner of the stored food and the real object of the "parasite" is the stored provender. It is therefore a robber rather than a parasite, unless we use the latter term in a very broad sense.

As to predatory forms, the order *Coleoptera* contains a great number. All those species that have filiform or thread-like antennæ, comprising the families *Cicindelidæ* (tiger-beetles), and *Carabidæ* (ground beetles), *Haliplidæ* (diving beetles), and *Dytiscidæ* (water tigers), are predominatingly feeders upon other insects. A few feed on vegetable tissues as well or as an alternate, and a very few seem confined to a plant diet; but, as a whole, this immense series of species feeds on other insects in both larval and adult stage.

Most of them are rather general feeders, taking all things that come in their way, and they are not at all particular whether this prey is another predatory form or a plant feeder. And we have species that frequent trees, shrubs and flowers as well as those confined to the ground: the smaller forms capable of feeding only upon eggs, the larger climbing trees for the caterpillars

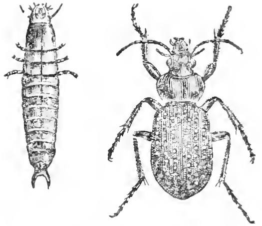

Fig. 44.—A caterpillar-hunting ground beetle and its larva.

Fig. 45.—A common type of ground beetle.

to be found on them. Some of the species have the advantage of being able to adapt themselves to the conditions found in cultivated fields and orchards and the number of larvæ and pupæ of plant-feeding forms that go under ground for pupation or hibernation that are destroyed by them is beyond all computation. While I do not recollect at this time any species that devotes itself to any one particular kind of prey, there is no sort of doubt of the reality of the check which the ground beetles exercise over the increase of plant-feeding forms—especially those which pupate on or under the surface. But we must limit this praise just a little: none of them bother with such small fry as plant lice and scale insects and their cannibalistic habits do much to limit their usefulness.

In the series of rove-beetles or *Staphylinidæ*, which are scavengers as a rule, there are many small species that are predaceous, and what a battle goes on between these and other breeders in or among damp, decaying vegetation we can only guess when, with a sieve, we collect out of a handful of forest leaves sometimes a dozen species of adult beetles and hundreds of minute larvæ and wriggling creatures of all sorts. The collector who covers a dozen miles in a day and at night has a box of butterflies, beetles and other insects to show for it, has seen much; but he has seen nothing of the intimate life of insects as compared with the man who has spent the same period in an open glade in a deciduous wood. It is not in the open air and on the surface that the most interesting matters are to be observed; it is under the shelter of fallen leaves, in the very centre of a decaying stump or log, or beneath a stone and sometimes deep in the very soil that insect life manifests itself in its most wonderful ways. It means patient watching and persistent study to unravel all these mysterious happenings that come to our attention, and it is because we have not yet done enough of this, that we know so very little about these rove-beetles and their minute allies; but we do know that they are not all scavengers at any rate.

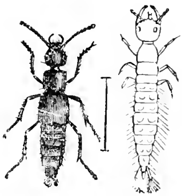

FIG. 46.—A rove-beetle and its larva.

Among the *Coccinellidæ* popularly known as "ladybirds," "ladybird beetles" or simply "ladybugs," we find a very decided specialization as to the character of the prey. Almost all the members of the family are predatory during the larval stage, but they are not general feeders; some of them are even very closely limited as to food, and form specific checks of the very highest importance. Remove one of these checks and the host may become immeasurably destructive: restore it and, no matter how much the host has gained, the check will regain control. Plant lice and scale insects are the especial prey of these beetles and the facts just recited are within the observation of almost every student of entomology. We are in the habit of thinking of "ladybird beetles" as being red or yellow in color with black spots, and as nearly hemispherical or at least convexly oval in form. The form is quite constant indeed, but the colors are by no means all gay. Besides the red, yellow and black species there are those that reach to metallic blue and yet others that are dull or shining black with very little if any maculation. The variation in size is also considerable, for while we have giants half an inch in length, we have also midgets not much more than one one-hundredth of an inch over all.

Is there any unusual increase of a plant louse or scale species: in a few weeks their ladybird enemies will be found to be on the increase as well, and very often, even before the end of the season, the control will be re-established; for many of these species have several broods during the year and plenty of food is conducive to quick development. Even a normally rare species may under such a spur become abundant. An example of such control I have seen on several occasions in the case of a plant louse that infests Norway maples, by the 15-spotted ladybird, which is not usually common. When weather conditions during early spring favor the plant lice they increase until June, when the first hot, dry spell puts a period to their work. An unusually cold, wet spring will be accompanied by an unusual abundance of lice, and on three occasions within twenty years when the cold, wet weather extended into late June, infestation became so serious that the leaves were covered with honey-dew and soot-fungus, so that they choked and began to drop. But about this time the ladybirds were also in the running and had become so numerous that they were fast reducing the plant lice and putting a period to the infestation. And then came the long deferred hot spell in early July, wiping out the plant lice as with a sponge and leaving thousands of beetle larvæ without food. What did they do? First the larvæ ate all the eggs of their own kind yet on the leaves; then they ate the helpless pupæ getting ready to change to the adult stage; then the large larvæ ate the smaller ones and as they became full fed and pupated, they in turn became victims to those that had escaped the slaughter. And before the end of July the 15-spotted ladybird beetle was again a rare insect and no outward sign remained to tell what crowds of them had been on the scene a month before.

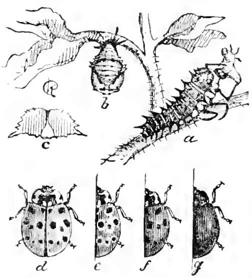

FIG. 47.—15-spotted lady-beetle: *a*, larva; *b*, pupa; *d-g*, adult varieties.

But not all Coccinellids are able to increase so rapidly; some species being strictly limited to one brood. The cottony maple scale in the east is controlled by the signate ladybird, *Hyperaspis signata*, a little black species with one red spot on each wing-cover. About once every decade the scale escapes control, and for a series of three or four years becomes increasingly abundant so that tree owners are thoroughly scared and demand remedial measures. Experience has enabled me to assure these owners that when matters are apparently getting serious, the worst is over; because by the end of the third year the *Hyperaspis* has caught up with its host and almost every scale

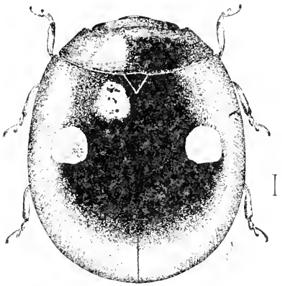

FIG. 48.—The signate lady-beetle.

egg mass contains one or more beetle larvæ feeding in and upon it. The year following, scales may be difficult to find and the *Hyperaspids* are forced to other species upon which they fail to maintain themselves and perish—all save a few that find enough congenial food to maintain the species.

What happens when an insect of this character is entirely freed from its normal check, was demonstrated in California when the cottony cushion scale, *Icerya purchasi*, was introduced from Australia without the *Vedalia cardinalis*. In a few years the *Icerya* had assumed the dimensions of a calamity and, as one excited grower informed me, even the hitching posts became infested. The introduction of the ladybird enemy which had been discovered in the native home of the scale turned the tables at once. In less time than it had taken the scale to overrun the country, the *Vedalia* aided by artificial breedings and distribution, cleaned it out, until now both scale and beetle barely maintain themselves. There are undoubtedly many other similar relations, but on this point we have yet much to learn.

It rarely happens that a *Coccinellid* beetle ranges far from its normal food or a very closely allied species, and however flexible and adaptable it may be in relation to its normal prey, it generally fails when pitted against an unknown or new form. The San José or pernicious scale is a rather close ally of several of our native armored scales, and the Coccinellids that feed upon these also attack this introduced form; but east of the Rocky Mountains none of them exercise the least real control over it. On the Pacific Coast the *Chilocorus bivulnerus* or twice-stabbed ladybird does act as an effective check because, having several broods during the season, it becomes plentiful enough to devour a large percentage of the hibernating forms. In the east this same species has only a single brood and is absolutely impotent. And when we brought in the closely allied Asiatic *Chilocorus similis* to help us out, that flourished for a year or two in one of our southern states and then died off. In the more northern states it never gained a foothold at all. The little *Smilia misella*, native to the Atlantic states, becomes plentiful enough at times, and may be found feeding even in midwinter; but while it undoubtedly helps to keep down numbers somewhat, it cannot be considered an effective enemy.

And so we have in these Coccinellid beetles a series of the most highly important checks to some of the most destructive insect types, the removal of which would cause a serious derangement of conditions as

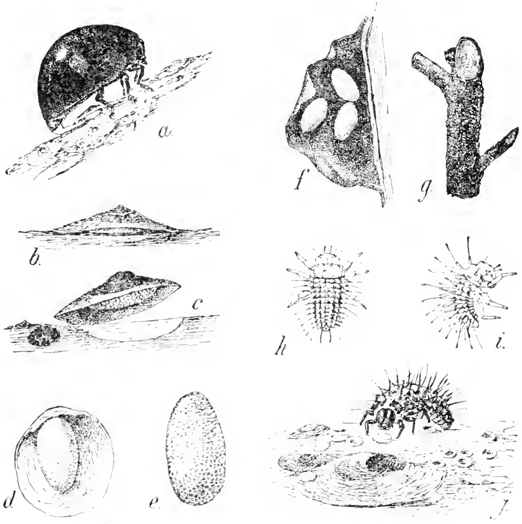


FIG. 49.—*Chilocorus similis*: *a*, beetle laying egg under scale; *b*, *c* scales showing egg in place; *d*, egg in scale; *e*, egg; *f*, eggs under bark flap; *g*, same, natural size; *h*, *i*, young larvæ, *j*, same feeding.

they at present exist. These checks are flexible within limits, and automatically, by simply devouring each other, restore themselves to inconspicuous numbers when their services are no longer needed. But we are not yet in position to train them to our service nor to induce them to feed on unfamiliar species.

In the family *Lampyridæ*, containing the fire-flies and soldier beetles, and among the flower beetles of the families *Malachidæ* and *Cleridæ*, we have a series of species of which a large number are predatory in the larval stages, while the adults are feeders on pollen or vegetable tissue. Among the fire-flies some of the larvæ are feeders on snails, while others, with those of the soldier beetles, are limited to an insect diet. They are largely found on the surface of the ground or just beneath it, and they get a great many of the plant-feeding forms that go underground to pupate. Withal they are rather general feeders and not specific checks. Among the *Cleridæ* the majority of the species are predatory on wood-boring forms, and some of them are specific checks on the bark-boring Scolytids. The larvæ are elongate, rather slender and flattened creatures with a large head and prominent jaws, and they enter into and follow the galleries of their prey, which is unable to escape and absolutely incapable of resistance. Under normal conditions these species are capable of dealing with a large percentage of the wood-borers; but it seems rather easy to turn the scale against them, and the Scolytids often do a great deal of injury when favored by careless forest practice, fire injury or other checks to tree development. Taken as a whole the predatory and semiparasitic forms among the beetles are a very important factor in keeping down plant-feeding forms and in preventing the undue increase of other species which are not directly harmful and may even be beneficial.

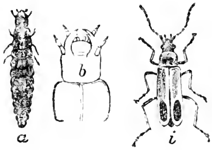

FIG. 50.—A soldier beetle and its larva.

The order *Lepidoptera* contains no parasites and very few species which, in the larval stage, are predatory. In the adult stage the mouth structure of butterflies and moths precludes their feeding on other than liquid food where they feed at all. A very few of the larvæ or caterpillars are predatory, feeding on scale insects or plant lice. Generally speaking these insect-feeding caterpillars are rare; but that of the little Phycitid *Lætilia coccidivora* is really a very effective control for certain of the soft scales. It is a species that belongs to the same series as the flour moths and meal moths, making the same sort of silken tube as a home; only, instead of webbing together kernels of wheat, etc., it spins up a mass of scales and feeds upon the eggs or young even before they have issued from beneath the mother body.

In the order *Diptera* we have a very interesting mixture of forms, including many that are of the highest importance as parasitic or predatory checks to other species; but we are less able to limit these species to certain families. Here we may have, in apparent close relation, species that as larvæ are plant feeders, scavengers and true parasites; and there is nothing in the adult which indicates the habit of the larva, so far as our studies have yet carried us. Even in the midges, which are certainly to be ranked as plant feeders, there are a few that have been credited with feeding on certain of the smaller plant lice. Among the *Culicidæ* or mosquitoes there are a number of larvæ that are truly predaceous, and a few of them, like those of *Psorophora*, are veritable wolves among the other wrigglers. They have the same fault that I have already deplored for other species:—they limit their own increase by feeding upon their brethren when other wrigglers have given out.

The blood-sucking flies are considered in another chapter and have no important relation to other insects, although some of the larvæ, notably those of the *Tabanidæ*, or horse-flies, live to some extent on other insect larvæ inhabiting swampy and marshy soil. The robber flies of the family *Asilidæ* are veritable falcons of the insect world and capture their prey by pouncing upon it in flight, sucking its juices by means of their powerful battery of lancets, and then discarding the dry husk. They are not at all particular as to what sort of species comes into their way,—a fly, a bee, a beetle or a butterfly,—anything answers. And so while they devour an enormous number of specimens, they are not specific checks to any line of plant feeders. Indeed, as a matter of fact the robber flies do not discriminate in the least: they will as cheerfully devour a dragon fly or a ground beetle as a butterfly or June-bug; it is all a matter of which comes along first.

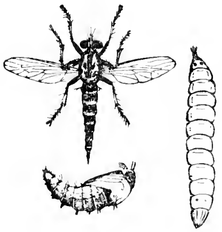

FIG. 51.—A robber fly, with larva and pupa.

Among the bee-flies or *Bombyliidæ*, we find in the larvæ both parasitic and predatory types, and forms which, like the blister beetles, devour the stored material of bees and other species. The adult flies themselves are often bright colored and hairy, some of them resembling bumble-bees in appearance and some with long, bee-like mouth parts. In the larval stage some are true parasites on caterpillars, notably cut-worms, while others feed in the egg-pods of grasshoppers, devouring all the eggs in a single pod in attaining full growth. Those that feed on the stored food in bee cells are cuckoos in habit and are effective in limiting bee increase. As parasites they are not of so much importance, for while they do their share in limiting numbers under normal conditions, they do not readily increase in abundance when the host becomes unusually plentiful. Of much greater importance are those species that depend upon grasshoppers; for these do really aid in effective control, the larvæ increasing in relative numbers as the egg-pods themselves

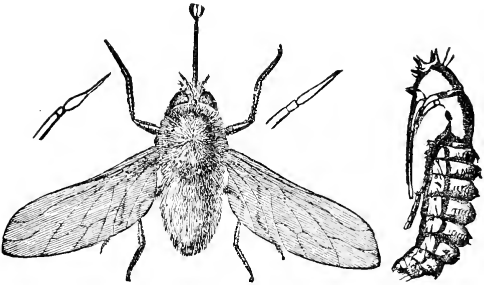

FIG. 52.—A bee-fly and its pupa.

become plentiful. There are other predatory larvæ among the *Empidæ* or dance flies and similar small families; but none of any great importance, until we reach the *Syrphidæ* or flower flies. Among these we find a large number that are specific feeders on plant lice and among their important checks.

In this connection it is interesting to note that in every order in which there are predatory insects at all, there are some that feed largely or exclusively on plant lice. We will also find, in another connection, that these same plant lice are also seriously influenced by diseases and weather conditions, and yet, in spite of all these factors, some species escape from their checks almost annually to the greater or less detriment of the plant hosts. And they always maintain themselves as against all these combined checks even when each exercises its maximum influence. It is easily appreciable, therefore, that when one or two of these factors fail, *e.g.*, weather and diseases, as not infrequently happens, it demands a great increase on the part of the other checks to prevent the Aphids from

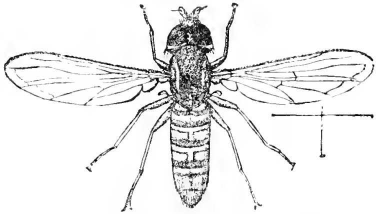

FIG. 53.—A Syrphid fly, *Mesograpta polita.*

getting out of hand altogether. The Coccinellid beetles have been already referred to in this connection and the larvæ of the Syrphid flies make a very good second. The flies lay their eggs in the very midst of the lice and the resulting larva, which is a slug-like creature without legs and with a very extensile anterior portion of the body, begins feeding at once on the specimen nearest at hand. This feeding is interesting, for the larva fixes the little hooks that serve it as jaws into the body of the louse, lifts it high in the air, and holds it thus helpless, until the juices have been completely extracted. As each of these slugs feeds almost continuously from ten days to three weeks, it gains gradually even on the plant lice surrounding it, and not only checks increase but lessens infestation. Not all the Syrphid flies are carnivorous, however; quite a number are scavengers, some are pollen feeders and others live in the tissues of succulent leaves or stems.

The really important parasitic group is found among the Tachinid flies and their close allies resembling house-flies, blow-flies, flesh-flies and others of that character. Some of them—the majority indeed—are inconspicuous grayish flies of moderate size; others are metallic blue or green, with or without stripes, more or

FIG. 54.—Syrphus larva eating plant louse.

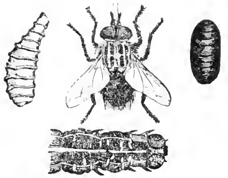

FIG. 55.—A Tachinid fly: its eggs on body of caterpillar, larva and pupa.

less spiny, while a few are large, set with long bristles and marked with contrasting colors, appearing formidable and dangerous, even if they are not actually so.

These flies lay their eggs on a variety of insects, but more frequently on caterpillars, and may be said to be specific checks to a great variety of cut-worms, including the army-worm. The eggs are often laid on the outside of the caterpillars just back of the head where the insect cannot reach them, and as they are white and of good size, they are easily seen. These Tachinids come nearer to being able to keep up with the increase of their hosts than almost any other forms that I know, and I have on several occasions seen army-worms on the march, almost every one of them with the seeds of death conspicuously placed upon them. Out of hundreds of pupæ gathered where armies had been feeding, only single examples of moths were obtained.

And in this connection we might note that a check to the further increase of any plant-feeding species does not necessarily mean an immediate cessation of injury. Indeed in the armies of parasitized caterpillars, every one fed until it was fully grown, and so far as injury to the crop was concerned, it made not an ounce of difference to the owner of the grain. And so we must realize clearly that all these natural checks are not imposed to prevent the plant-feeding insects from injuring the farmer's crop, but simply to prevent undue increase in relation to the surroundings and to preserve the balance of nature.

Yet these Tachinid flies are among the most effective engines of destruction to the species which they infest. They develop quickly, the females lay a large number of eggs and they are themselves not seriously affected by secondary parasites. They are therefore able to maintain their relative proportion to their host no matter how rapidly that multiplies because of the removal of other checks.

Not all Tachinids lay their eggs directly on the body of the host. It has recently been demonstrated by a series of most interesting observations made in the course of the gypsy moth work in Massachusetts, that some species lay very small eggs on the leaves of infested trees and that these eggs, eaten by the caterpillar with the leaf tissue, hatch when they get into the stomach and bore through the walls into the body cavity. Yet other forms lay their eggs on leaves, on which caterpillars are feeding, fastening each to the surface by a little capsule which serves to hold the active young larva that hatches almost as soon as the egg is laid. Sooner or later the feeding caterpillar comes within range of this waiting maggot and then with a dart the parasite hooks into the skin of its host, is torn from the capsule attached to the leaf and bores its way in. It will be readily appreciated that this plan of scattering the numerous minute eggs over the foliage on which caterpillars are feeding is likely to reach the hosts in proportion to their abundance. If, for instance, a brood of gypsies completely strips a tree, every Tachinid egg on it will also get into the caterpillar stomachs to the undoing of a vast percentage of them. It seems like a hap-hazard way of doing things and, no doubt, when caterpillars are scarce, very few of the thousands of Tachinid eggs ever find their way into any appropriate host.

It is in the order *Hymenoptera*, including the bees, wasps, ants and the like, that we find the most interesting specializations in the way of predaceous and parasitic habits; specializations so numerous and interesting that they demand volumes for their proper presentation and can be only referred to here.

First of all, there is that enormous series of solitary wasps, including the mud-wasps, digger-wasps, wood-wasps and whatever other modifications of the term may be employed; all of which make cells of some kind either in the ground, in pithy stalks, against an angle, in a crevice or even attached to a twig, and these cells are stored with food enough to bring the larva to maturity. Most of the wasp larvæ are helpless, footless creatures, absolutely incapable of seeking their own food, and they depend altogether upon the store that has been gathered by the parent, and that store consists largely of insects or spiders, which are paralyzed by stinging the nerve-centres and then retain life enough to remain without decaying until the wasp larva has reached maturity. One of the commonest examples of this sort is seen in the shapeless cell made by our blue mud-wasps under porches, between the slats of shutters, under the eaves or even in garrets. If we open one of these cells in summer we find it stored with small motionless caterpillars or spiders, and either an egg or an actively feeding wasp larva among them.

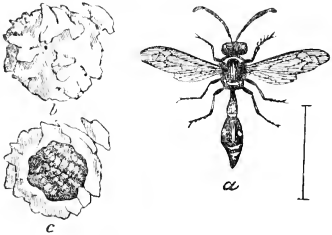


FIG. 56.—A potter-wasp, *Eumenes fraterna*, at *a*, its cell *b* broken open at *c*, to show stored caterpillars.

On the same order, but much more neatly built, are the mud cells of the potter-wasps, which we find frequently attached to low bushes. These are usually filled with small caterpillars, all very much of a size, and so closely packed as to fill the cell completely. As every one of these cells requires from ten to twenty larvæ to fill it and a single wasp makes a dozen or more cells, the number of specimens thus used up becomes quite a factor. Not all wasps feed on caterpillars; indeed, there is scarcely an order that is not fed upon. Some digger-wasps fill their cells with grasshoppers; others, that make their cells in the hollow shoots of pithy plants, collect plant lice, the larvæ of small beetles, flies, or even other *Hymenoptera*. There is hardly a species so small as not to be attractive to some of the smaller wasps, and on the other hand, the largest Cicada or tarantula is not safe from these formidable enemies. When large species are fed upon, a single specimen often serves to bring a larva to maturity. The "taran-

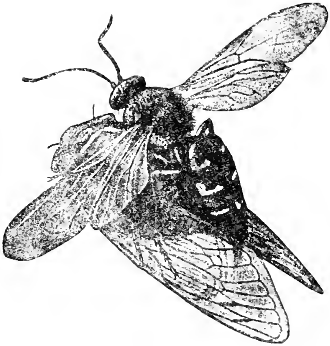

FIG. 57.—*Sphecius speciosus* carrying a cicada to its home.

tula hawk," when it has succeeded in finding a suitable spider, and has succeeded in quieting it with the formidable sting, buries its prey and lays a single egg on it. We have quite a number of wasps that do little more than bury their host and lay an egg on it. The handsome large *Sphecius* that preys on the Cicadas or dog-day harvest-flies, makes a burrow with several laterals, in each of which it stores a specimen or two which serve to bring to maturity one of the wasp larvæ. There is an exotic species living on one of the large roaches, which, after stinging its prey so as to deprive it of voluntary motion, is said to seize it by an antenna and lead it into a sheltered spot before it deposits the egg. The roach simply stays where it was led until the wasp larva kills it by feeding.

This method of stupefying prey is a very high specialization and the stinging is by no means a haphazard one. The wasp seeks the thoracic ganglion of the nervous system of adult insects, and may sting several ganglia in caterpillars, to make them entirely quiet. The poison introduced is said to resemble formic acid in composition and to act as a preservative as well as a paralyzing agent. But this preservative effect has been disputed and there are yet many interesting points to be elucidated in the biology of these predatory wasps. The number of specimens collected and stored by them is very little appreciated, but it is enormous, and the reduction in the number of specimens thus preyed upon forms a very important factor in the check to undue increase.

The social or paper-making wasps are also feeders upon insects; but not so exclusively, and they make no store of food for their larvæ. They feed the young from day to day with prepared food, chewed into proper condition by the nurses, and consisting partly of insect fragments and partly of plant juices.

Ants destroy many insects, but do not usually make specific war upon any one species. They are very apt to attack, kill and eat almost any sort of helpless creature that they find, but few of the species of the temperate zone feed largely enough upon insect food to form a notable check to any species.

Several families are exclusively or almost exclusively parasitic, and these range in size from forms so small as to be scarcely visible to the untrained eye, to specimens expanding two inches or more, with ovipositors four or five inches long. Very often, especially among the smaller species, the colors are brilliantly metallic, and they range all the way from smoothly shining to deeply pitted as to surface.

There is no species so small and none so well concealed in feeding as to save it from parasites, and these latter may infest any stage from the egg to the adult. It is not unusual to find a batch of "bug" (*Hemipterous*) eggs and to hatch from them a brood of minute wasps instead of the little bugs that were expected. And when a lot of pupæ or chrysalids have

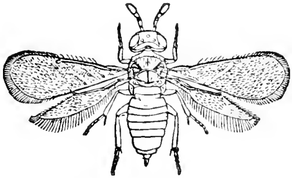

FIG. 58.—*Aphelinus*, parasite on armored scales.

been collected, the result may be butterflies or moths, but is just as likely to be several hundred or only a few parasites instead. The size of the chrysalis is no indication of the number of parasites to be expected. Out of a large *Papilio* or swallow-tail we may get a single large *Trogus* and out of a small *Pieris* or cabbage butterfly we may get one hundred or more little bronze Chalcids. On a twig infested by scales one may often see a large percentage with little round holes through the shell—proof positive that from each a minute little wasp has issued; and on a leaf infested by plant lice, we often see some that are abnormally swollen or rounded and tending to turn gray. These also are parasitized and will shortly show a nice little round hole through an empty skin as a reminder of the tragedy. Such parasites not only kill the individual, but at once stop all reproduction, so that every infested louse is at once eliminated as a factor in the increase of the species.

There are several families of these parasitic wasplets; there is an enormous number of species, often of the most bizarre type of structure and with extreme diversity in habits. Some species remain within the body of their host until they emerge as adults, often giving no indication of infestation; others, when fully grown, bore out through the skin and form little white cocoons on the surface. Some of the large Sphinx caterpillars or horn-worms are often covered with so many of these little cocoons as to make them conspicuous objects. And not infrequently the farmer or gardener carefully destroys these particular specimens, because, in his opinion, they are covered with eggs—forgetting the fact that a caterpillar is incapable of reproduction until it has first become a butterfly or moth.

Fig. 59.—Sphinx caterpillar covered with cocoons of parasites.

A few species, usually those feeding on borers, are external feeders, the parasitic larva clinging to the outside of its host and sucking its juices through a small opening in the skin.

Some parasites proclaim their character by an external protruding ovipositor or egg-laying tube, while others have it modified into a sting-like organ. The sting throughout the *Hymenoptera* is nothing more than a modified ovipositor, and that explains why only females of bees, wasps, ants, etc., have it. When the ovipositor is external and extended, it varies greatly in length. Sometimes it is short and rigid, almost like a little borer, at others it is long, slender and flexible, like a hair or bristle. Many of these elongated types are found among species that attack boring insects and some are quite capable of piercing deeply into woody tissues. Excellent examples of this type are found in the species of *Thalessa*, which expand nearly two inches and have ovipositors almost or quite four inches in length. These are parasitic on boring

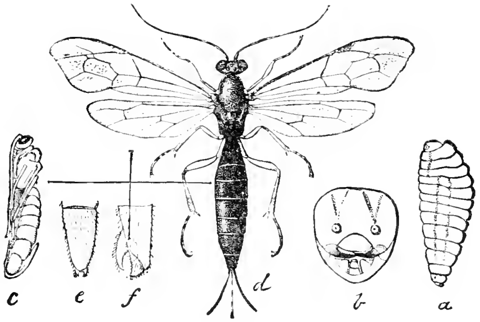


FIG. 60.—*Pimpla conquisitor;* a common parasite, with its larva and pupa.

larvæ of the genus *Tremex* which live in burrows in the trunks of maple and other trees. In some way these huge parasites seem able to recognize infested trees and to locate, at least approximately, the burrows in which the borers are working. Then the long ovipositor comes into play, and by a unique mechanical contrivance the slender, bristle-like structure is forced into the solid wood for sometimes its full length before the desired burrow is reached and an egg can be deposited. It would be asking too much that the ovipositor should hit the exact point where the borer happens to be at the time, and when the parasitic egg is once in the gallery, the mother insect has done her work. The young larva that hatches in the burrow makes its way along until it finds its prey, attaches itself, and calmly enjoys life at the expense of its host. But the mother insect is by no means infallible, and sometimes her ovipositor fails to hit a boring, either because it is too deeply located or because it has been missed by bad judgment; then nothing remains but to try over again. Sometimes, in a vigorously growing tree, the sappy wood grips the ovipositor and holds so tightly that it cannot be moved one way or the other. Every one who has ever tried sawing through a green log knows what sort of grip such wood may have, and the unfortunate *Thalessa* that is caught in that way is doomed—usually to be picked off by some inquisitive bird, sometimes to die of over-exertion. I have several times tried to draw out ovipositors caught in that way and have never succeeded: the ovipositor always broke under the strain put upon it.

Maturing as quickly as many of them do, they are able, as a rule, to keep up with any unusual increase of their host, and to enable them to do this even more effectively, some species have developed the remarkable ability of producing a large number of specimens from one egg—polyembryony, as it is called. One of these minute species finds, for instance, a butterfly egg, and in that lays its own egg, so minute in size as not to interfere with the normal development of the caterpillar which hatches in due time, but with that parasite egg within its body. The caterpillar grows and so does the parasite; but instead of forming a larva and growing normally, this parasitic egg forms a structure which divides and subdivides and gives off segments almost like those of a tape-worm. Each of these segments forms a larva which develops as the host develops and finally, when the latter is full grown, it is filled with minute, maggot-like grubs ready to form pupa cases which will fill the caterpillar skin so completely that it seems ready to burst. From a single parasite egg, we may thus get fifty or more adults; but they will all be of one sex as determined by the egg originally laid. It will be readily seen what enormous reproductive powers some of these minute specimens really have, for even if each laid only ten eggs and each egg produced fifty adults, the progeny would still number 500: not at all bad for such small creatures!

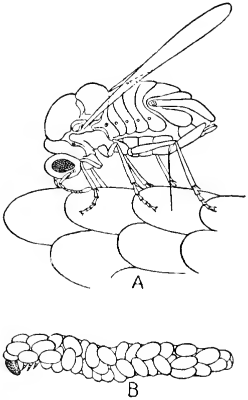


FIG. 61.—*a*. *Listomastix* parasite laying a single egg in the egg of a moth; *b*. the full-grown caterpillar with parasitic cocoons from the single egg. After Marchal.

With such enormous powers of reproduction, it seems surprising that the hosts are not completely exterminated; and yet as we know, they are not. If we collect chrysalids of cabbage butterflies in spring, the chances are that out of one hundred we may get ten butterflies and several thousand parasites; more than enough it would seem to overpower the next brood of caterpillars completely. But now, if we collect full-grown caterpillars from the scant lot produced by the few spring butterflies, we are likely to get a butterfly from every caterpillar. From the second brood we are likely to get almost as clean a record, and then butterflies become so plentiful that the last brood of caterpillars plays havoc in our cabbage fields. By this time the parasites are in evidence again, and the hibernating chrysalids are as badly infested as they were the year before. The parasite has accomplished its full purpose, the butterflies are not conspicuously more abundant than they were the spring before; but throughout the summer the farmer's cabbage has paid the bill imposed by nature's methods.

There is yet another factor in this connection, and that is the matter of what is known as *hyper-parasitism*, *i.e.*, a parasite on a parasite. Not only do these parasites infest predatory forms in other orders, as for instance the larvæ and even adult ladybird beetles, but they infest primary parasites among the *Diptera* and in the *Hymenoptera*, very materially reducing their effectiveness as checks from the human standpoint, but serving an important part in preserving nature's balance and preventing the extermination of the primary host. The terrific extent of this secondary parasitism can best be illustrated by recording a personal experience. I sorted out of a collection of cocoons of the Cecropia moth 295 specimens that were obviously parasitized. Of these seventy-six specimens were infested by *Ophion* containing only a single example to each cocoon; the others contained species of *Spilochalcis* and *Spilocryptus*, each cocoon with a mass of at least twenty examples. Out of these I bred nineteen specimens of *Ophion*, the others dying of disease, fifty-one specimens of *Spilochalcis* and 126 specimens of *Spilocryptus*: but in addition I also bred nearly 50,000 specimens of *Dibrachis*, a secondary parasite upon the two primaries! And the matter goes even further: for besides secondary parasites we may have others infesting these, or tertiary parasites, checking in turn too great a reduction among the primaries.

It is a merry war in which all these organisms are engaged, each one aiming only at food for itself and its progeny, and yet each playing its part in that game of life in which man seems to be the only one capable of appreciating the conditions, though he is himself involved and a sufferer as well as a factor in the game.

It is a pleasure to be able to say that the relation of active hostility is not the only one existing between insects. Between some there is at least toleration; as between others an active friendship based on mutual advantage; in a few cases there is almost absolute dependence.

The first case of this kind that comes to mind is the relation of certain ants to certain plant lice, and assuredly we have nothing in the range of insect behavior that exceeds in interest this cultivation or fostering of a creature so far different, until we get it in the relation of the human being to his domestic animals. The relation is even closer, because so much has the lapse of time acted upon this interdependence that, while the elimination of the plant louse might make little difference to the ant, the elimination of the ant would, in many cases, mean the destruction of the plant louse.

It is not possible in this connection to do more than mention the fact that among the social insects there are a number of different castes and forms, each of which has its own function in the community. That is a matter of internal administration and is regulated by each species in accordance with the conditions which have been developed by the stress of the surroundings. It is a little different when the matter of slavery comes to be considered; when we find that certain species of ants actually make war upon weaker forms to obtain servants to do their work; and yet even this is a matter of domestic economy to be covered rather by a student who, like Dr. William Morton Wheeler, has studied the ants in their relation to each other, than by a general work, dealing rather with the relations of different kinds of insects.

In the domestic economy of ants, we have to consider those species which are of use to the ants themselves and are fostered and cultivated for that reason, and those that maintain themselves in the nests in spite of opposition or by toleration only. The first series are those from which the ants derive a direct benefit; the others are those which do them no direct harm and rather indirectly benefit them.

Perhaps plant lice are the best known of those that are directly fostered, and they are favored because of the saccharine secretion or "honey" which they produce. The simplest form of this relation is where ants visit colonies of plant lice on vegetation and, by stimulating or irritating the specimens with their antennæ, induce them to eject a drop of the sweet secretion which is then gathered up. In return the ants attack and drive off a great many enemies that would otherwise destroy their herds. The next stage is when ants build galleries around roots infested by plant lice and directly favor them by freeing from soil and other incumbrances an abundance of feeding surface. This would seem to give the plant lice a free field for increase; but not only do parasites find their way into the nests but even larvæ of ladybird beetles occur in considerable numbers. These latter, however, in almost every case, produce from specialized glandular structures, waxy fibres which seem almost or quite as attractive to the ants as the secretions of the plant lice. They therefore feed upon these processes or rather excretions, and appear to forgive the intruders their trespasses against the Aphids. A still further specialization, decidedly more important from the economic standpoint, is found among those ants that gather and preserve the eggs of plant lice during the fall and winter, and colonize them on suitable food plants in the spring. The strawberry louse and corn-root louse are examples of this kind, and both of these Aphids would find it difficult if not impossible to maintain themselves were it not for the assistance given by the ants. The economic importance of the matter comes in when we consider that, except for the ants, it would be easy to starve out the Aphids by a mere rotation of crops. In some instances, where the plant lice will not live underground, the ants build protecting shelters around the colonies on their food plants, and thus gain all the advantages that other species get from their underground forms.

Indirectly, therefore, ants may become decidedly injurious to a growing crop, even though they do not themselves feed upon it, and the best way of dealing with an injurious form may be through its protecting ant.

Besides plant lice, scales are often visited and here again the protection accorded by ants in the destruction of forms inimical to the scales is the return rendered for the food supply. It has been charged, indeed, that the *Scutellista* introduced into California to control the black scale, has been practically destroyed by ants that obtain honey-dew from the scales. Scales, however, are never really domesticated like plant lice, and while they are of very great importance to some ants they are never entirely dependent upon them for existence. Some few species among the tree-hoppers and frog-hoppers, also excreting honey-dew or waxy matter, are found in the nests or galleries of ants, and are at least tolerated if not directly favored.

Then, as in all great cities, so the large formicaries are inhabited by a rabble of scavengers, thieves, messmates of all kinds, living in friendly or hostile relations as the case may be. These are of the most diverse characters, from the lowly Thysanuran to the fellow ant of smaller size or dominating type. Over 1000 species of Myrmecophiles, as such species are called, have been already listed and their habits more or less fully studied and there is no doubt that there are at least as many more. Some of these, like a variety of rove-beetles and some other of the Clavicorn series, are scavengers, living on the decaying particles of organic matter found in the galleries, and may repay the ants by excretory substances coming from specialized tufts of hair or glandular surfaces.

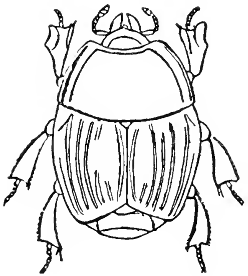

FIG. 62.—*Hister* species found in ants' nests.

These are favored and protected, while others that pay nothing for their living usually keep out of the way as much as possible. Some few species, belonging to the *Histeridæ* or pill beetles, are positively harmful to the colonies, but are so well protected by their shining armor of chitin, that the ants can do nothing with them. It is a case of simply enduring what cannot be cured, and such intruders must be constantly on their guard not to expose leg or antenna when the owners of the nest are about. A few caterpillars have been found in formicaries and these feed on the dead leaves in, over, or about the nests. The ants seem to pay little attention to any save a few Lycaenid larvæ that have glandular structures producing attractive secretions. A few species of small crickets and other *Orthoptera* help to swell the list of guests, and several fly larvæ occur. Some of these inhabitants steal the supplies gathered by the owners of the nest, and against these relentless war is waged whenever the ants recognize them; but there are curiosities in ant intelligence which, in some cases, seems to amount to downright stupidity, and which prevents them from recognizing the thieves in the most vulnerable stage. Perhaps the worst thieves in the formicaries of large species are other, much smaller ants that run their narrow galleries so as to tap the larger tunnels, and when they are detected stealing disappear into their own streets into which the larger form cannot follow. There are also direct parasites adapted to live in such communities without recognition, but only mere mention can be made of these. There is a good deal of human nature in an ant city and the history of what takes place in such a city has been written most accurately and entertainingly by Dr. Wheeler, who is on terms of most intimate acquaintance with these species.

## CHAPTER V.

### THEIR RELATION TO THE ANIMALS THAT FEED ON THEM

This subject might be dismissed with a very few words in the statement that a large number of birds subsists entirely on insect food, another large number feeds on insects during certain seasons or takes them indifferently as part of the general diet, and that the same is true of certain mammals, reptiles, batrachians and the like. Active defence very few insects are able to make against any of these enemies, and we may say broadly that the number of insects that may be destroyed by vertebrate enemies is limited only by their appetite and their ability to find prey. The only practical defences that an insect has, are its ability to escape the notice of its pursuer and its enormous fecundity; points that have been elucidated to some extent in a previous chapter.

So we can say, roughly, that all kinds of insects serve as food for some kind of animal. That is not strictly true, of course, for there are some that are so minute that they are taken only by accident and a few others that seem to be so offensive that no animal will touch them; but as a general statement it is accurate enough. Some birds and animals eat indifferently any thing that comes along; others have a very limited diet and go outside of their normal range only under the pressure of necessity, which is usually spelled hunger. Some animals eat what others avoid, *e.g.*, hairy caterpillars, and some insects feed so as to be out of reach of all save animals especially adapted to find them, *e.g.*, borers sought by woodpeckers.

Among animal feeders on insects we may enumerate toads, frogs, snakes, lizards and all their relatives; the tortoises generally; rats and mice and their allies; the shrews and their allies; bats, coons, opossums, moles and, to a less extent, the larger carnivora. The smaller species of the cat and dog tribe eat a large number of insects and even bears count them among their list of eatables. Fish eat the aquatic species whenever they can get at them, and birds have been already referred to. Now, when we realize that the insectivores among the mammals form a very numerous and important series, and that the carnivores assist, we get at once a formidable list of destroyers against which, as already stated, the insects have little defence. The matter of protective resemblance of course comes in; but that plays really a very subordinate part. There is no doubt that many insects resemble their surroundings so closely that they are with difficulty to be seen; but they can be seen by the trained eye. Some species of moths sit openly on the tree trunks in city streets and hundreds of passers-by absolutely fail to see them; but to the first entomologist that comes along they are as obvious as if they had been placed there to attract his attention. It would be ranking bird and animal senses very low indeed if we seriously believed that such resemblances made them actually invisible to those who have in hunger the best sharpener for the senses that can be imagined. That such resemblances do protect from casual marauders there is little doubt, and that there is a better chance of escape from a casual search than there would be were the insects more conspicuous we may assume; but that the resemblance is protective to the extent that is sometimes claimed is at least open to serious doubt.

"Playing possum" is a much better protection, and is resorted to by many insects. This means that when they are disturbed and apprehend danger, the specimens draw in legs and feelers, permit themselves to drop to the ground and remain absolutely quiescent until they believe the danger past. This very habit, however, delivers some of the economically important species into the hands of their arch-enemy man, who spreads a sheet or other catcher beneath a tree or vine, jars the infested plant and gathers in the specimens which on the white background are conspicuous enough, though in sod or on the bare earth they would be well-nigh invisible.

Warning colors and protective mimicry are other passive defenses. Warning colors are simply bright or contrasting tints that indicate a species unpalatable to ordinary animal feeders on insects of that description. That there are such species there is no doubt, for they seem almost entirely safe from predatory foes. Their dress expresses the legend "not good to eat" and so they are left unharmed. Now one type of protective mimicry is found where a species of another group or series normally good to eat so closely resembles this unpalatable form as to be readily mistaken for it, and some of these resemblances are extremely close. Another type is when an inoffensive insect so closely resembles one that is capable of defence, that its enemies hesitate to attack. The resemblance of some Sesiid moths and Conopid flies to wasps is a case in point. In such instances it is quite usual to find that the mimic has some of the same tricks of habit as the protected form and this is at least as powerful a safeguard as the color alone.

Now what place do these vertebrate enemies hold in the series of checks to insect increase, and how much do they benefit man—the farmer and fruit grower?

We have here two questions of very great interest and importance and the answer to the one does not by any means determine the answer to the other. That all these birds and other animals eat untold thousands of insects each year is undoubtedly true, and that this is an important factor in limiting the number of specimens, is unquestionable; but compared with the numbers destroyed by disease, by climatic conditions and by other insects, the figures are really insignificant. It goes without saying that these remarks are based on normal, natural conditions, for it is quite possible to change the conclusion under control. For instance, if I turn a flock of guinea-hens into a field infested with grasshoppers, the fate of those hoppers is sealed, provided there are guineas enough to eat them. I have seen some fields of alfalfa, however, in the foothills of the Rocky Mountains, where the grasshoppers were so numerous that all the guineas within the county would make no serious impression on them.

As to the food of birds we are left in little doubt. Many species have been shot in large numbers at all seasons and have had the stomach contents carefully determined and classified. One striking fact that appears from all the lists that have been published, is that the large majority of insect feeders among the birds pick up anything they can get hold of most easily, and that the commonest reasonably palatable forms are those most frequently taken. Naturally, though, this does not apply to birds fitted for a special diet like the woodpeckers. Among the other animals almost the same conclusion applies, again making exceptions of such creatures as moles and others which are naturally limited to underground forms or to species occurring in limited or specialized areas.

One consequence of this is that a great many economically harmless insects furnish a large percentage of the food: ants, flies, fly larvæ in excrement and similar species. Another is, that a great many positively useful insects are taken; less so those of absolute importance to man by reason of their direct contributions than those indirect friends, the predatory and parasitic forms; and spiders may for this purpose be counted as useful insects. Furthermore birds do not discriminate between insects that are parasitized and those that are not. Hence in eating cut-worms there is at least an even chance that parasitized forms are taken as freely as those not so infested. In eating a parasitized specimen the only benefit derived by cutting short its life is the saving of its food for a few days, because it could not have come to the reproductive stage anyway; while a positive harm has been done in cutting short the parasites which might have destroyed a hundred cut-worms the season following. It is always possible to draw a variety of conclusions from a list of insects found in bird stomachs, and that generally drawn, to wit, that birds are always of very great importance to the farmer and fruit-grower, is usually no more warranted than the contrary one that birds are of no use whatever.

There never yet was an apple orchard kept free from codling moth by birds no matter how much chance the birds had: in fact in neglected old orchards where birds and other animals are never disturbed it is rather the exception to find a fruit free from insect attack. The same is true of the plum curculio. There never yet was a field of grain freed of green-fly by birds, nor a tree of any kind saved by them from destruction by San José scale. In many cases woodpeckers do more real injury to a tree than the larva they get out would have done, and the elm in a grove where birds hold undisturbed sway is just as likely to be defoliated by the elm-leaf beetle as its fellow in the city streets where the English sparrow holds the fort. It is correct to say that as against the common pests of the farm, the field, the orchard and the garden, neither birds nor other vertebrate animals are of the least practical benefit and that the farmer and fruit-grower would as to them be no worse off if every insectivorous bird and other animal were killed.

And yet withal it is not a fair conclusion, to contend that insectivorous birds and animals do no good. They do, no doubt, constitute a very useful and important check to many species that would otherwise be much more abundant than they are, and a careful preservation of every insectivorous bird and animal is good policy—even such forms as quail, partridges and their allies, which are now guarded at one season simply that they may be shot at another.

It must again be emphasized that birds and other animals constitute only one of the checks to insect increase and, as against climate, disease, parasitic and predatory insects, a very minor and insignificant one. We must also remember again that for a naturally abundant species the abundance was fixed in spite of all the natural checks, including birds and animals. Now when such an abundant insect becomes destructive by reason of undue increase from any cause, the very last factor to become important in bringing it back to normal conditions is the vertebrate enemy list, including birds, because their number and ability to consume remains practically a fixed quantity due to their slow rate of multiplication. It sounds large when we find 100 larvæ of an elm-leaf beetle in a bird stomach and find 100 birds to an acre; but when we find 100 larvæ on a dozen leaves and many thousands of leaves on a tree, the figures lose in impressiveness.

It must be realized that under natural conditions insectivorous animals depend on insects for their continued existence, and that when fed to the full, there must yet remain enough to supply food for the season to come in spite of all other natural checks, as otherwise the animals, birds and others, would themselves starve to death. I have already pointed out how peculiarly well some of the parasitic and predatory forms are adapted to gain control of a runaway species, and it remains to be added that among the effective forms that check the undue increase of parasites, are the birds and other animals that eat parasites and parasitized insects.

Now, in spite of the fact that I am convinced that all vertebrate animal life, so far as it affects the insects that are injurious to our farm crops, is of little real benefit to the farmer and fruit-grower, I would not for a moment argue in favor of the destruction of any form of bird or animal life not absolutely harmful to cultivated crops. Birds have their place in preserving the balance of nature and any interference with them is sure to react unfavorably to the agriculturist by increasing his troubles in some direction; and while under normal conditions birds may be of little value, yet under abnormal conditions which tend to remove checks of other kinds, any increase in bird and similar enemies would assist in replacing the other checks.

I would, therefore, rigidly protect every insectivorous bird and other animal, including non-venomous snakes and toads, and I would also protect every animal that feeds upon insects at any time, providing the direct injury done to crops or other farm products is not at any time sufficient to cause appreciable loss to agriculturists.

I would not hesitate advising the destruction of robins, crows, blackbirds or others when actually engaged in feeding on fruit or grain; but I would absolutely prohibit their killing at any time as a mere matter of sport. I would be in favor of protecting every bird not absolutely harmful; but of no protection whatever to any animal merely for the purpose of keeping it to be shot at during some specified period by so-called sportsmen.

I have no point of difference with those who are seeking the protection of bird and other animal life. I simply wish to record my disagreement with some of the reasons and arguments advanced by them, and to guard against an exaggerated belief in the value and usefulness of our furred and feathered friends.

Interference with natural conditions by introducing new factors does not always turn out well and should not be resorted to without a careful preliminary study of possible consequences from all points of view. When the English sparrow was introduced into North America only one point was kept in mind: get something that will eat the span-worm, the larva of the geometrid moth, *Ennomos subsignaria.* The sparrow really did accomplish that feat; but is now a greater nuisance than the span-worms ever were and is a direct protector of certain species which never occur in troublesome numbers outside the region dominated by it. The common Tussock or vaporer moth of the east is an excellent example of this, and hardly less striking is the case of the wood-leopard moth which has not become injurious in this country anywhere except in cities and towns where the sparrows keep all other birds out.

Chickens, ducks, geese, and especially turkeys and guinea-fowl are great feeders on insect life and may sometimes be used practically, and the useful hog esteems wire-worms, white grubs and similar creatures as tid-bits to be eagerly sought and worthy of considerable rooting for.

# CHAPTER VI

## THEIR RELATION TO WEATHER AND DISEASES THAT AFFECT THEM

Very few insects occur throughout the world, and those that do are usually such as have been distributed by or have followed in the track of man or his commerce; but there is no portion of our globe where life occurs at all, in which insects are not found. In the polar regions they are often unpleasantly conspicuous, and in the tropics they frequently render life burdensome. When the arctic snows begin to melt during the short summer and form puddles on the mossy surface, mosquito larvæ appear, and even when there is an ice coating over the pools at times they maintain themselves and come to maturity. Indeed some wrigglers and other insects will stand freezing or imbedding in ice, and come out none the worse when a warmer temperature thaws them into a liquid medium. There are insects, then, that survive in one condition or another the extremes of arctic cold: there are others that flourish under the opposite conditions of tropical heat. Indeed the luxuriant vegetation of the equatorial regions is accompanied by an infinite variety of insect life, a variety so great that we have just begun to appreciate it, and which will give a field for study to entomologists for generations to come. Furthermore, as we have found aquatic forms in water at temperatures low enough to form ice, so we find others in waters whose temperature ranges close to the boiling point. There are some regions so arid that neither vegetable nor animal life exists in them; but if at any time under the influence of rain, vegetation appears at all, insects will be found on it. And again, some insects occur in midocean among masses of seaweed, undergo their transformations and develop generation after generation without ever coming within reach of land.

So we find that there is no climate and almost no earthly condition in or under which insects do not exist; yet, on the other hand, insects are, as a rule, extremely sensitive to changes in climatic conditions, and some of them succumb easily to any extreme range of temperature, even within their native home. Zoologists have divided the world into faunal regions based on climate, and have subdivided these into smaller regions based on the geographical conformation of the country whose fauna is under consideration; and we have found in our studies that a large number of insect species have an extremely restricted faunal range. Beyond that range they do not thrive at all, and not infrequently, where no natural barrier seems to exist, spread nevertheless does not take place. The check in such cases is weather in the broad sense of that term, or, more accurately, the meteorological conditions. The mere fact that any species of insect is regionally distributed usually indicates that any climatic condition not normal to such region would be fatal to it. An apparent exception occurs when insects are confined to one food plant—the occurrence of such plant being then a condition precedent to its existence at all. But this is merely shifting factors about a little, for usually the climatic conditions determine the distribution of the plant and, in consequence, really of the insect as well.

We know that occasionally we have abnormal seasons, and sometimes several seasons of the same kind may occur in succession. When that happens insects may begin a migration beyond their original limits and may extend a long distance into adjacent territory, only to be destroyed when a recurrence of normal weather conditions renders the invaded area unfit as a place of habitation. An example of that character occurred in 1896 when the Harlequin cabbage bug invaded New Jersey and Pennsylvania, its normal range not extending north of Maryland along the Atlantic coast. But although it was present in that year in destructive numbers, it was completely killed off during the winter following and has not been found in New Jersey since. It is an example of an insect rigorously restricted in distribution by climatic conditions, although its food plants are widely distributed outside of its own faunal limitations.

But occasionally matters do not terminate as simply. It may happen that an insect long confined to a definite faunal area may be started on a migration along the line of its food plant, and may be found to possess sufficient powers of adaptation to continue its life under conditions varying materially from those in which it started. A striking example of this is found in the case of the *Sphinx catalpæ* which in its caterpillar stage feeds only on Catalpa and which, up to a few years ago, did not range north of Virginia and Kentucky, although its food plant extends into New York and Pennsylvania. Somewhere about 1897 it began to extend northward through Maryland and Delaware into Pennsylvania, and year by year it has extended that range until it has reached the headwaters of the Delaware River, and has extended throughout New Jersey into New York State. And this extension is not of a few individuals only; but of a horde, capable of causing defoliation and serious injury to the trees attacked. At present it seems as if the species had succeeded in establishing itself in a faunal region definitely varying from that in which it started; but there are indications also that it has reached its limit.

A yet more striking case is found in the migration of the cotton-boll weevil, a species indigenous south of the line between Mexico and the United States, which began its invasion into our territory somewhere about 1893 and has been annually extending its range through the cotton-growing states since that time. So great a variety of climatic conditions is now represented in its distribution, that there seems to be no reason to believe that its spread will be checked until it has reached the faunal limits of its food plant; although that period may be materially retarded by the quarantine and other regulations now adopted by the cotton-growing states.

These are instances of natural spread from one faunal region to one adjacent thereto, along the line of the food plant. There are other cases where insects have been accidentally introduced on trees, shrubs or plants from one country to another, into which it could not have spread naturally and where the climatic conditions in the new home suited the species so much better that injury became much more severe as specimens became more numerous. An example of this character is found in the recent introduction of the "white-fly" of the Citrus from Florida to California, where the dry climate exempts the insect from certain disease and other checks favored by the more humid climate of the eastern country.

Leaving aside for the moment cases where migrations have been from south to north when, under favoring conditions insects from mild temperature regions extended into normally more rigorous climates, it sometimes happens that conditions reverse, and instead of a higher temperature extending northward, a low temperature extends southward. This is rarely followed or accompanied by a southward migration, but is very frequently attended by a great mortality among the southern insects which are unable to withstand the drop in temperature. Some species, indeed, are so sensitive to cold that a drop of 10° or even 5° below the normal winter temperature causes a serious mortality.

Besides temperature, the amount of moisture has a very decided effect on insect life. Some species do best in dry weather, others flourish only when there is an abundance of moisture, and sometimes a sudden change from one condition to another will produce a complete change in insect conditions within twenty-four hours. Thripids as a rule require dry weather, and after a period of drought and heat, the air may be full of the little creatures not over an eighth of an inch in length and so slender as to be almost invisible. A cold rain lasting a few hours may reduce them to so small a number as to make them practically undiscoverable. Agriculturists sometimes take advantage of this peculiarity by spraying infested plants with cold water, and that is really about as satisfactory a method of control as we have.

Every one who observes nature at all, has probably noticed that in some seasons insects are much more abundant than they are in others, and, more specifically, certain kinds may be almost completely absent or on the other hand frightfully abundant. Now in most cases these differences are largely and in some even exclusively due to climatic conditions. There is no greater check to insect life than adverse weather, and many of the differences in abundance attributed to other causes are really due to climate.

During a wet spring certain species of plant lice may become so abundant as to threaten a given crop, with their natural enemies so far in the rear as to seem hopelessly out of the running. A sudden change to hot dry weather will change conditions so radically, that within a week the lice are gone, while ladybird larvæ and other plant louse destroyers are feeding upon each other.

No kind of insect is more sensitive to weather changes than are the Aphids, and few of them are able to resist a sudden change of temperature exceeding 30° in range; but an increase is not nearly so fatal to most of them as a sudden drop. By the term sudden I mean within an hour or two, because ranges of 30° or over within twenty-four hours, are not uncommon in most portions of the United States.

The character of the winter has much to do with the abundance of insects during the summer following. It is not so much the hard or the mild winter as the variable winter that is fatal to insect life. When an insect goes into hibernation in either larval or adult stage it becomes torpid and capable of resisting all usual degrees of cold. Even if the cold is long continued at its most intense point it makes little difference and, in general, we may say that a continuously severe winter is favorable to insect life. The insect simply remains torpid and no change in condition occurs. On the other hand if there are alternations of freezing and thawing, the insect may become partially or altogether active and again torpid, losing in vitality at every change until it dies or reaches spring in such condition as to be unable to complete its tranformations or to reproduce its kind. Such alternations are particularly hard on pupæ and on larvæ that winter underground in cells. A thaw results in softening the ground and partially disintegrating the walls of the cell: a heavy frost following heaves the surface, and the water in the soil in freezing breaks up the cells completely, bringing the soil into direct contact with the soft insects, crushing or otherwise destroying them.

A variable winter, therefore, is a hard one on insect life, and during the summer following certain species are likely to be conspicuous by their absence. It is such factors as these that tend to limit a fauna; only species capable of withstanding their variations being capable of continued existence under them. The common and widely distributed species are those that have become adapted to a wide range of temperature and relative humidity; the others are more limited as to the conditions under which they can exist and die off in proportionately large numbers when conditions are adverse.

While climatic conditions are important factors in limiting both numbers and distribution, they are perhaps more effective in limiting distribution, since the occurrence of a species within a faunal region presupposes an adaptation to its normal ranges of temperature and moisture. A more effective agent in limiting numbers is found in the diseases to which insects are subject, and yet the effectiveness of diseases as a check is in large part due to climatic conditions, most of them developing best or only in moist hot weather.

Insects suffer severely from epidemic diseases due to micro-organisms—fungus and bacterial—and of these diseases we know, as yet, comparatively little. Almost every observant individual has seen late in the season, attached to a window pane, specimens of the common house-fly with abdomen distended and a little whitish powder surrounding the points of attachment. Such flies have been killed by a disease that is contagious and frequently kills large numbers of specimens. Grasshoppers are often seen dead and dry, on top of some stalk of grass or at the tip of some weed, and this death also is due to disease. When we break up such a grasshopper we find it filled with a powdery mass—the spores of the disease that caused death. Caterpillars are sometimes found presenting a peculiarly limp appearance, and these when touched prove but a pasty mass of bacterial organisms. On a cabbage leaf infested by plant lice we may almost always find a portion that are dull yellowish-brown in color and opaque: victims of disease, easily distinguishable from the parasitized examples which are more distended and somewhat shining or glazed. And so in every order, attacking either larvæ or adults, there are diseases that lie in wait for them and carry off large percentages. Some of these diseases have been long known and their effectiveness is so great that efforts have been made to propagate with the view of using them practically. But it was found that, while some effect was always produced, and while some diseases seemed equally effective year after year, others acted only when weather conditions were just right and were therefore unreliable, because these conditions could not be controlled even though the germs of the disease might be supplied.

The most extensive and most interesting experiments of this nature were carried on a few years ago in some of the states of the central west against the chinch-bug, which is one of the most serious enemies to grain and corn culture in those sections. The chinch-bug is a sucking insect belonging to the order *Hemiptera*, and therefore cannot be reached by any stomach poison. It is killable by certain contact insecticides, but the task of spraying the enormous grain and corn fields of Kansas and other states of that section loomed up so large and expensive, that it seemed discouraging. In the exhaustive study carried on by a number of entomologists, it was noticed that the species was subject to certain diseases and that at least one of these was often epidemic in character and capable of being propagated. The suggestion was therefore made that this disease furnished the natural method for dealing with the insect, and field experiments seemed to bear out the suggestion. The result was the establishment of laboratories for the propagation and distribution of chinch-bug disease, in almost every state subject to chinch-bug attack, and the introduction of the disease into every section where the insect occurred in sufficient numbers to attract attention. There were some wonderfully successful results reported, and fully as many absolute failures, and this eventuated in the discovery, after much patient observation, that the chinch-bug flourished and delighted in dry weather, being most active and vigorous in droughty times, when the food plants themselves were in the poorest condition to withstand attack. In times of moisture the bugs were sluggish, inert, and low in vitality, while the plants, on the other hand, were vigorous and capable of out-growing and resisting injury. The disease, on its part, would not develop nor spread in dry weather when the bugs were most troublesome; but it did spread like wild-fire in a wet season when it was least needed. As a dependence to check the spread of the insects when danger was imminent, the experiment was a failure; but the practice was nevertheless a success, because the disease has now been introduced everywhere and is a constant danger to the bugs, reducing them to such small numbers during moist seasons that in dry seasons there are not enough of them living over to become dangerous. It would now require a series of two or three dry seasons in succession to provide for a dangerous outbreak. And this seems, in a way, to measure our present ability to use diseases as a check to insect increase, *i.e.*, we can plant them where they will lie dormant and ready to fall upon the insects whenever conditions become favorable. Our knowledge is as yet altogether too rudimentary to enable us to predict future possibilities.

A disease of the grasshopper has been referred to, and this has formed a subject for extensive research work in South Africa where the migratory forms are among the most destructive pests. It was found that there is a disease that sometimes appears among the flying hordes and destroys enormous numbers of them. This disease has been studied, has been propagated on culture media, and has been distributed in pure cultures with directions as to how swarms may be infected through a prepared food. They depend in this instance upon infecting bran, meal or a similar material with the disease culture, to be exposed where the wingless grasshoppers will find and eat it. They thus become inoculated with the germs and establish the disease in the swarms in which it afterwards spreads naturally. The results on these South African forms are said to be very satisfactory. The attempts to establish the same disease in our American species have not produced any marked results as yet.

Scale insects are quite subject to disease attack, especially in climates like that of Florida, where certain of the armored scales are kept at harmless numbers by fungi. One of these attacked the San José or pernicious scale when it was introduced into that region, keeping it down without much assistance on the part of the fruit-growers. Efforts to introduce this disease into

Illinois and New Jersey succeeded in so far that it was actually established, but proved utterly incapable of catching up with the insects during the hot dry spells of midsummer when it rested dormant, while the scale flourished and multiplied. When rains came, the temperature fell below that needed by the disease, and we found an evident case of climatic limitation. Evidences of the existence of the disease may even now be found in New Jersey in some localities, ten years after it was first introduced; but it never yet cleared even a single tree of scales!

This brings up a point of some interest and much importance: the length of time during which a disease may lie dormant and retain its virulence. On this point our information is very scant; but an example in illustration may be given. The periodical Cicada, or "17-year locust" as it is more popularly known, is attacked in the adult condition by a fungus disease that attacks the body of the male, destroys the sexual organs and causes the abdomen to drop, so that during the latter days of a Cicada invasion a large percentage of male examples will be found mutilated in this way. So far as is known this disease attacks no other insects, and for seventeen years it lies dormant, somewhere, ready to become active again when a new brood makes its appearance.

Certain kinds of plant lice are always more or less attacked by disease, and some show more diseased than parasitized specimens at all times. Indeed I am inclined to believe that, aside from temperature conditions, diseases are the most effective of all checks to plant lice increase; but so far as I am aware, no attempts have yet been made to use any of them practically. Perhaps I should guard myself here against being misunderstood. I am quite aware that some species of plant lice are so heavily parasitized that even when they get a good start early in the year, their enemies usually overhaul them before they have destroyed or even severely injured their host plant; nevertheless I am ready to allow my statement to stand as an expression of general conditions, applicable to the ordinary run of species.

I have already referred to the fact that caterpillars are subject to disease and the check to certain species is, I believe, much greater than is generally recognized. On that point I made a very interesting study on a large series of light cocoons of the Cecropia moth, finding that more than two thirds of all the caterpillars died of some trouble other than parasites after the cocoons had been completed, but before the change to pupa had taken place. Others as well as I have observed entire broods of caterpillars dying, and one of the characteristic attitudes of such diseased caterpillars is that the twig or leaf is clasped by the prolegs along the sides of the body, while the portions anterior and posterior to this hang limp and lifeless. Eventually the whole thing dries and shrivels up almost to a skin. This sort of condition I observed in Massachusetts in 1907, in territory infested by gypsy and brown-tail moths; fully 50 per cent. of all the larvæ seen showing evidences of disease: and that condition existed to a still greater extent in 1906, when a large proportion of the caterpillars of the brown-tail moth were wiped out of existence.

This is eminently one of those cases where an earnest effort should be made to use the disease-producing organisms to check increase and spread, and the study of the subject has been actually taken up. It is quite probable that it will be found that the disease has its limitations, and that it requires certain climatic conditions for its greatest efficiency. But we can, at least, follow up the spread of the insects with the disease, and by getting the germs into every colony as fast as it is established, introduce a check which is ready to act when conditions become favorable, and which may, in some localities, control it absolutely.

Only a small number of insects have been specifically mentioned as suffering from disease attack; but this does not begin to indicate the actual extent to which they suffer, nor the varying character of the infestations. And it is not only those species that live above ground on trees or foliage that are affected. Some of the underground forms like white grubs, wireworms and others are subject to the attacks of growths which change the entire insect into a corky mass, giving rise in some cases to processes that reach above ground as though the grub itself had begun to sprout. The extent to which such conditions occur we cannot estimate because they are mostly out of our view; but we do not find them often enough to indicate that they exercise any great influence upon the number of examples that come to maturity.

Among aquatic insects diseases also occur, and I have frequently lost entire broods of mosquito larvæ that have been the subject of some trouble which caused a cheesy degeneration.

Every breeder of insects has had some of his cages infected with disease germs so that every brood subsequently introduced died off altogether or in large part, and the experienced man to whom this happened destroyed those cages altogether if he could, or cleaned, disinfected and exposed them to the action of the sun and air if for any reason keeping them was necessary. He realized that, once established, a germ disease was extremely difficult to get rid of by any but the most drastic measures. Many years ago the breeders of silk-worms in France found their caterpillars dying at such a rate as to threaten the very existence of the industry. It was a germ disease of course, but nothing was known of such things at that time and it afforded an opportunity for Pasteur to win renown and to benefit his fellows to a degree that few in that or any other country have really appreciated. It gave a striking illustration of what epidemic disease could do under favorable conditions, and it is still suggestive as to possibilities when we attempt to reverse the Pasteur objective.

At the present time many bee-colonies are suffering from what is known as "foul-brood," a disease or diseases of micro-organic origin which carries off enormous numbers of specimens annually. The character of the organisms causing these diseases is now known and, in a general way, the treatment to be adopted, so there is nothing at all mysterious except the negligence of the bee-keeper who permits the disease to develop unchecked in so many instances. It is probably rare that an insect once attacked by disease, recovers. In my breeding experiences and in field observations I have never known of such a case. I have often seen among a brood that sickened, one or a very few individuals that showed no trace of disease, that fed normally and developed naturally; but I have never seen such a larva show signs of the sickness and then resume growth; so in a general way these diseases may be considered as fatal when they once gain a foothold.

We have now seen that, while in general there are no conditions of climate where insects do not occur, yet climatic conditions may and do in many cases check not only the distribution but the numbers of insects: that while many species are fitted to live under widely varying conditions, others are adaptable within very narrow limits only, and succumb readily to variations beyond the normal range.

We have seen also that, not only do insects suffer from germ diseases, but that these often assume the dimensions of epidemics and form a very important factor in nature's scheme of insect control; a factor of which we have not yet made the utmost possible use in our dealing with the economically important species.

# CHAPTER VII

## THEIR RELATION TO OTHER ANIMALS

In the course of their development insects have established the closest kind of relations to the rest of the animal kingdom, and there is scarcely a vertebrate terrestrial animal that is not more or less affected by parasites—man not excluded. Some of this parasitism is of the most highly specialized character. We have somehow come to think of parasites as being simple, lowly organized creatures, of very inferior rank, and yet a moment's thought will show that there could be no parasites of vertebrates until the vertebrates themselves existed, and as the insects long antedated vertebrates, parasitism must have come as a specialization from an already well-developed organism.

Nor is such parasitism confined to what we call the lower orders, for we find none of it in the *Thysanura* or primitive forms; but its most elaborate development occurs in the *Diptera*, or flies, which are the highest in the scale so far as physiological specialization goes.

As might be supposed, the *Hemiptera*, gaining their food by piercing and sucking, rank well among the orders containing animal parasites; indeed, broadly speaking, a large percentage of the order is strictly parasitic on either plants or animals. The scale insects, for instance, are absolutely dependent upon the host plants to which they attach themselves, and many of them if once removed from their attachment, are helpless and die. The plant lice are less strictly parasitic and yet the term "lice" is a good one when we compare it with the same term used for those suckers that feed on vertebrate blood. But the parasitism here is of an exceedingly simple character, and means only the adaptation of the external form to a life among fur, hair or feathers, and the development of some sort of structures to hold on with.

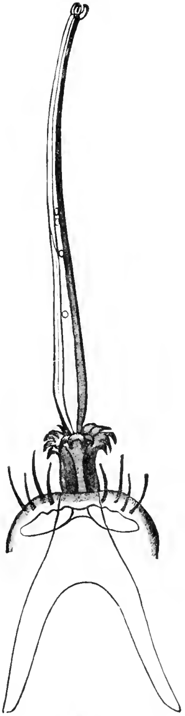

Fig. 63.—Mouth parts of a sucking louse.

Most hairy animals, from the little field mouse through all the ruminants to man himself, are subject to the attacks of sucking lice. Now, while man cannot be strictly ranged as a hairy animal nowadays, some of his anthropoid allies come conveniently under such a definition, and the few species that infest humanity are some of the remaining disadvantages of a former closer relationship with ape-like forms. That man has been in this comparatively hairless condition for a long time is shown by the fact that one of his parasites has become especially adapted to life under such conditions, and that another has undergone an even more profound modification in habit since he was a clothed animal.

These sucking lice are, in general, small flattened creatures, gray, whitish or yellowish in color, with an elongate oval body or abdomen covered with short hair or spines, and a more or less pointed head from which a pair of slender styles or lancets may be protruded. In many cases there is at the base of these sucking structures a series of recurved hooks or small horny processes, by means of which the creature anchors itself in the tissue of its host and sucks at its convenience. Such structures are apt to be developed in forms infesting animals with rather scant short hair, where some method of holding fast is desirable. Another development is on the feet, where the tarsal

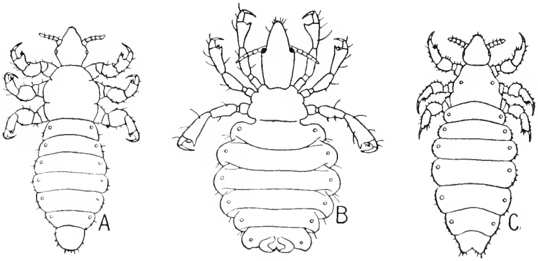


FIG. 64.—*a*, body louse of man; *b*, hog louse; *c*, head louse of man.

joints are arranged so as to be opposable to the end of the tibia, like a thumb. In this structure an individual hair is seized and held so tightly that it may be pulled from its socket sooner than the insect from it. This type has been called "scansorial" or climbing, because the insect moves about by grasping the hair nearest to its position and pulling itself along from one foothold to another. An extremely pretty illustration of this sort is found in the hog louse, and another in the crab louse of man.

By far the greater number of these parasites attach their eggs directly to the hair or bristles of their host, and pass their entire life upon it. They are incapable of existence away from this host and have no power of gaining food from any other source. The young are not very different except in size, from the adults, and there is no obvious metamorphosis.

Three species live on man and their distribution is coincident with that of humanity. The head louse, *Pediculus capitis*, lives among the longer hair of the body, usually confined to the head. Its legs are not scansorial, it has the anchoring process at the base of the head well-developed, and the eggs or "nits" are attached to the hair. The crab louse, *Phthirius inguinalis*, lives among the coarser, less abundant hair of the pubic and axillary regions and in hairy individuals also on other parts of the body. The legs here are scansorial, as of necessity they must be to enable the insect to maintain itself, and it also glues its eggs to the hair among which it lives. The body louse, *Pediculus vestimenti*, lives among the thinner body hair and almost altogether on parts normally covered by clothing. Its legs are not well fitted for grasping, but the anchor processes of the mouth are well developed. The peculiarity of this species is that it remains on the body of the host only while it is feeding and at other times hides in his clothing, where also it deposits its eggs. Man, therefore, has worn clothing for a period long enough to enable this parasite to adapt its mode of life to this habit, and to depend upon his garments for protection and as a nidus for its ova.

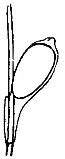

Fig. 65.—An egg or nit, attached to a hair.

These parasites sometimes become exceedingly abundant when men are herded together in camps, ships, or prisons, and specific irritations known as *Pediculosis* and *Phthiriasis* are produced by them. It has been calculated that a single adult female of the body louse might have, in eight weeks, a progeny of 5000, and while this is not equal to the performances of some other insects it does, nevertheless, serve to make possible a very rapid and complete infestation where they are allowed to develop unchecked.

Of course personal cleanliness is the best of all methods to be and become free from such parasitism; but infestation in modern conveyances is always possible, and with even the greatest care a parasite may obtain a foothold. Children, who are not always choice in their companions, not infrequently become infested by head lice. A fine-tooth comb and a thorough greasing of the hair with pomade or any fatty material, repeated twice at intervals of a week each, will clear out the parasites. The grease enters into and clogs the breathing pores of the lice and chokes them; but it does not affect the eggs or "nits." The later applications are intended to reach the young that have hatched from the eggs since the previous ones. As the eggs may remain unhatched for ten days or two weeks, this period of time will be necessary to insure freedom.

As for the body louse, the infested clothing should be discarded for a time. Underclothing may be subjected to lengthy boiling to kill both adults and eggs. Outer garments should be steamed or baked if possible, or should be dipped into gasoline; this latter application to be repeated in ten days, to reach later hatchings. The gasoline process is simplest as it kills all the adults at once, and if it can be repeated at short intervals, the clothing can be worn in the periods between treatments.

The crab louse is treated by local applications of mercurial ointment or by tincture of larkspur (*Delphinium*), the latter of which is also used against the head louse.

The habit that some savages have of covering themselves with grease, oil or paint, is not entirely without practical advantage, for thereby they do undoubtedly keep themselves measurably free from these parasitic forms. The use of ants to rid infested clothing of parasites is referred to by Mark Twain in his inimitable way, and it was a recognized practice in the far west in olden days, when changes of clothing were not readily obtainable, and when lodgings and lodgers could not be chosen but had to be accepted as found. It meant simply stripping naked, and placing all the clothing on an ant hill, where it would be immediately invaded by the ants anxious to attack and destroy every living thing on or in this foreign material. In a short time the clothing could be again put on with the comforting assurance that it was at least temporarily free.

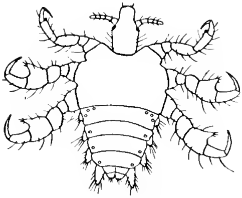

FIG. 66.—Crab louse of man.

Most of our hairy domestic animals are subject to the attacks of similar parasites, each of which lives and propagates on the body of its respective host. Spread from one animal to another occurs when they are in contact in stables, or herded closely together for shade in the pasture. Sometimes a parasite leaves its host voluntarily or is rubbed off by it in the stable, kennel or field. It may then crawl about on woodwork, plant or tree, hiding in crevices until another host animal comes into such a position as to enable it to crawl among the hair or wool.

As uncivilized man greases or paints himself, so animals have developed a method for securing freedom from parasites: they dust themselves or coat themselves with mud. The spiracles of most lice are not well protected, so when animals get into a dusty road and roll about, this serves a very practical purpose and those that get into a mud hole and wallow are often seeking similar relief. Other species of *Hemiptera* preying upon man will be considered under the heading of household pests.

Besides the sucking lice belonging to the order *Hemiptera*, many animals and most birds are also subject to the attacks of biting lice, belonging to the order *Mallophaga*, which means, literally, wool-eaters, and is somewhat misleading. Commonly they are also known as "bird-lice" because they very usually infest the feathered tribe. In color and appearance they do not much differ from the sucking lice; but the head is usually more blunt, and instead of puncturing the skin and living on blood, they have mouth parts formed for chewing and biting, and live rather on the surface scales and scurf at the roots of the hair and feathers. They do not puncture the skin to reach blood, but will feed on clotted blood at the edge of any wound and may prevent healing, or even cause the extension of a sore spot. And so, while a few individuals on the skin cause little inconvenience or unpleasant effect, yet when a great number are at work, the feeding at the base of the hair and of the smaller feathers results in the death of these out-growths and the infested animal becomes "mangy" in appearance. The true mange is, of course, due to a mite parasite of quite a different kind; but that "mange" which consists of bare spots on a hairy animal or thin plumage on a chicken or other bird, is very apt to be due to biting lice. In breeding habits they resemble the Pediculids very nearly: the eggs are fastened to the hair or feathers and there is little apparent change in outward appearance from the nymph just out of the egg, to the adult ready to reproduce. None of these species are found on man; but nearly all farm animals and all the domesticated birds are likely to become infested, each with its own

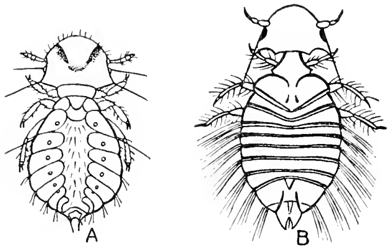


Fig. 67.—*a*, chicken louse; *b*, turkey louse.

peculiar species. It is rare that one species of parasite is found on two species of animals not very closely allied; but it is not uncommon for a single species of animal to harbor two or more kinds of parasites.

Birds are as fond of a powder bath as are the four-footed animals, and poultry keepers have long recognized the importance of the dust box in keeping their charges in good condition. It should always be the finest of dust available and there should always be plenty of it in a box of generous size so that even the largest bird can cover itself thoroughly without scattering the material beyond the edge of the container.

Horses and cattle can be very readily freed from lice parasites by a free use of curry-comb and brush, and if occasionally the brush be dipped into a pan of crude petroleum so that the tips of the bristles become wet, the coat of the animal will be materially improved, and any louse that is hit will be killed. Kerosene must not be used because that is likely to kill the hair; but crude petroleum acts as a stimulant and improves its growth.

There are no animal parasites in the other Neuropterous orders, and in the great order *Coleoptera* or beetles there are very few. We have scavengers and feeders on dead and decaying material in great abundance, and many beetles live with specific animals in very close relationship; but very few actually occur on the animals themselves. In the United States the members of the family *Platypsyllidæ* and *Leptinidæ* are known to live on the beaver and a few other rodents that have a dense fur. Just what the relation of these parasites is to the host is not entirely clear, but the larvæ do not live on it, and feed rather on the waste material in the nests.

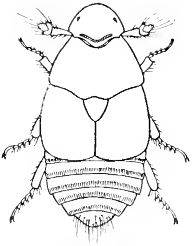

Fig. 68. — *Platypsylla castoris:* parasite on beaver. After Westwood.

Animal parasites would scarcely be expected among the order *Lepidoptera*, or butterflies and moths, and strictly speaking there are none. Yet it is certain that some of the small moths belonging to the Tineids, which include our "clothes moths," do actually breed and develop in the fur or wool of animals like the sloth, certain sheep, etc. There is such a thing, then, as a fur or pelt becoming moth-eaten, even while it still covers the body of its owner.

The great order *Hymenoptera*, in which insect parasitism is developed to a remarkable extent, contains no species that live on vertebrate animals.

The *Diptera*, or flies, on the other hand, in which specialization has been almost as extreme as in the *Hymenoptera*, have developed a considerable number of forms that depend for their living entirely upon the higher animals.

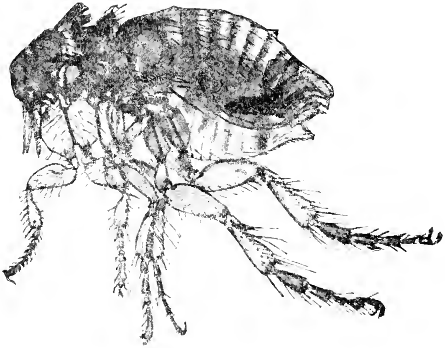

Fig. 69.—A rabbit flea.

The little family of fleas, which are very highly specialized flies, although now usually classed in an order by themselves, are all parasites on warm-blooded animals covered with hair or feathers. They are small, brown, transversely flattened, set with spines or stiff hair directed backward, and the legs are powerful, fitted for jumping. This characteristic form makes it very easy for them to move about among the hair and feathers, and this they do in a sort of jerky way as if they were making short jumps, each of which carries them a shorter or longer distance and enables them to easily avoid the paw or foot of the animal when it scratches the place where it feels a bite. Although parasitic in so far as it lives during its adult stage upon the host animal, yet the insect moves about freely, and the early stages are passed in most if not all cases among the litter in the nest or den of the host, and not on its body. In its early stages, then, the flea is not a

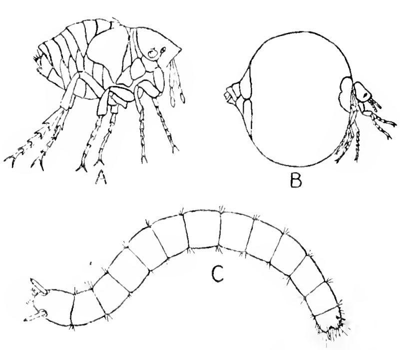


FIG. 70 —The jigger flea: *a*, normal female; *b*, distended with eggs; *c*, larva.

parasite, but rather a scavenger; in its adult stage it feeds on blood and differs from mosquitoes and other flies that have the same habit, chiefly in remaining on the host animal during the period when it is not feeding. As soon as an animal is dead and cold the fleas leave it. Of fleas in their relation to man there will be more to say in a later chapter.

There is one little group of fleas roughly known as "jiggers" that depart somewhat from the normal life history. In these species the female after copulation seeks some host into which it may burrow or imbed itself. Any animal, including man, will serve, and entrance is usually made between the toes or under toe-nails or claws, because penetration is easiest there. When once in position under the skin, the body of the female enlarges as the eggs develop until it is as big as a pea in an extremely painful and usually festering tumor. The eggs, when ready to be laid, are discharged into the sore, and the wriggling larvæ make their way out as best they can, to develop as do others of their kind. Animals often suffer severely from the attacks of these pests which inhabit the southern parts of our country and the tropics, and man is not infrequently attacked where he goes bare-footed. Where "jiggers" are well known the nature of the attack is usually recognized at once, and the insect removed with a needle or a knife-point; sometimes a wet quid of tobacco is tied over the infested spot for a few hours, and this softens the skin and usually kills the pest so that removal is easy. If the matter is neglected and removal is not attempted until the eggs are developed, the work must be carefully done so as to avoid breaking the body of the female and discharging the eggs into the wound.

Usually, on domestic animals, cleanliness and the free use of lime where the larvæ breed is sufficient to avoid trouble. But in some sandy regions fowls suffer severely from the species that attacks them. The hen flea is an ally of the "jigger" and while it does not bore into the tissue of the bird, the female does fasten itself firmly into the skin and remains attached until disturbed by some outside force. On young chicks they often fasten to the head and neck in such numbers as to kill their host. A free use of carbolated vaseline is indicated in cases of that kind. This material not only kills the fleas but acts as a disinfectant and promotes the healing of the sores.

There are many other kinds of fleas and they infest almost every sort of animal capable of affording them shelter; but there is a very general agreement in life history and in the character of the methods to be used in their control when control becomes a matter of importance. Some further word concerning these insects as carriers of disease will be found in a subsequent chapter, where also the closer relation of those fleas that occasionally occur in our houses is more fully elucidated.

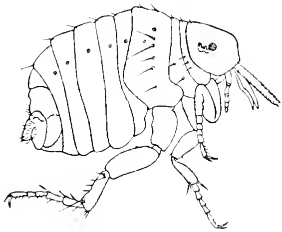

FIG. 71.—Chicken flea.

Among the true flies there are a great number of species that prey upon vertebrate animals, and they do this in two ways: either by feeding upon them in the adult stage alone, or by actually living upon them in early stages, and thus becoming true parasites. As the flies are among the most recent of insects, so their relations to the vertebrates, the most recent developments in the higher animals, are also most close.

The simplest form of relationship is that afforded by the various blood-sucking flies—the mosquitoes, gnats, midges, horse-flies, stable flies and others allied to them. In all these species the mouth structures are developed into a series of long slender lancets formed so as to be able to puncture the skin of the host and to suck the blood beneath it. In almost every instance the early stages are passed elsewhere than on the host that serves as food in the adult stage, and sometimes not even in the same medium. The mosquitoes, for instance, attack all sorts of vertebrates, cold-blooded as well as warm-blooded; but so far as known, all the larvæ are strictly aquatic, dwellers in water and adapted to secure their food only in that medium. Yet while the direct relations between animals and mosquitoes are simple enough, the indirect influence that they exert as intermediate hosts for certain disease-producing organisms are of so great importance as to require more specific treatment in another connection.

The *Simuliidæ*, containing those species known as "black flies," "midges," "Buffalo gnats" and others of similar character, are in somewhat the same case. The adults feed on warm-blooded animals, the larvæ are found only in water usually adhering to stones, logs, roots or other points of attachment and gaining their food supply entirely from beneath the surface. As both mosquitoes and gnats develop in water, their presence as adults in some localities is coincident, and a better combination for making life miserable can scarcely be imagined. The gnats are preferably day fliers, the mosquitoes preferably night fliers, so the entire diurnal cycle is thus provided for. The "black flies" do not worry their victims by buzzing or "singing." They are extremely business-like in their method and as soon as they alight they set to work. Their puncture is recognizable at once and resembles the prick of a hot, very fine needle, much more than any other bite known to me. The mouth parts are short, not nearly so compact as those of the mosquitoes, and the flies appear to veritably dig into the skin leaving, when driven off, a wound large enough to bleed—a butchery of which no mosquito is ever guilty. The small black flies, usually called "midges," are not content to attack only the exposed parts of the body: they crawl into the ears, the nose, under the clothing at the ankles, wrists or neck, and where a novice goes

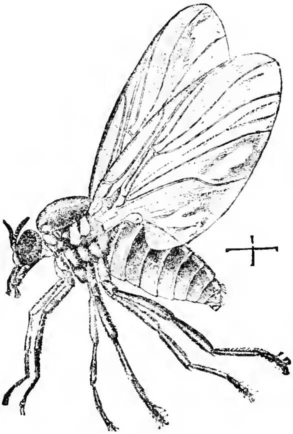

Fig. 72.—"Buffalo gnat" or "black fly."

unprepared into an infested territory, he usually stays there only as long as is absolutely necessary. Even the veteran is sometimes forced to run when he has not provided himself with some repellant substance. Of these "dopes" there are various sorts known to the woodmen, and their basis is usually a cotton-seed or olive oil, with an admixture of oil of tar, oil of penny-royal, menthol or some similar volatile oil. Oil of citionella is in great favor with many and, in my own experience is a little the most satisfactory and agreeable. The odor is offensive to others, however, and these may find the menthol preparations more satisfactory. Cattle and animals not being able to resort to repellants often suffer cruelly, and in countries where buffalo and similar larger gnats are plentiful, they are sometimes driven literally insane by the pain and irritation of the attack.

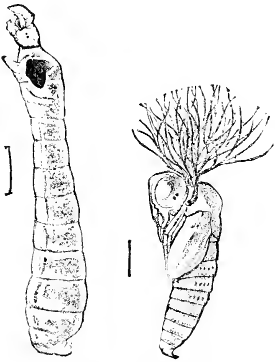

Fig. 73.—Larva and pupa of buffalo gnat.

The early stages being passed continually under the water surface, offer no points for an attack with oils. No matter how the upper layer may be coated, the insects on the bottom will be little or not at all disturbed, and as they usually inhabit running streams, it is practically impossible to maintain a surface covering anyhow. Those species that attach themselves to logs and sunken or surface-lodged tree trunks or the like, may be mitigated by cleaning out such obstructions and points of attachment; but for such species as attach themselves to stones on the bottom we have no remedy that is not also likely to be fatal to fish and other forms of aquatic life. Thus far no charge has ever been made against any of the *Simuliidæ* that they are carriers of disease in man or animals; but our actual acquaintance with the flies and with the diseases of the animals that inhabit their territory is slight, so that it would hardly be safe to say that they are not dangerous in such direction.

The *Tabanidæ*, including those forms known as "horse-flies," "deer-flies," "green-heads," "breeze-flies," "golden-eyed flies," and perhaps a number of other popular terms, are all much larger species, some of them among the largest in the order. They are all blood suckers in the female and feeders on nectar or other plant secretions in the male. In fact the males are as shy and retiring as the females are bold and obtru-

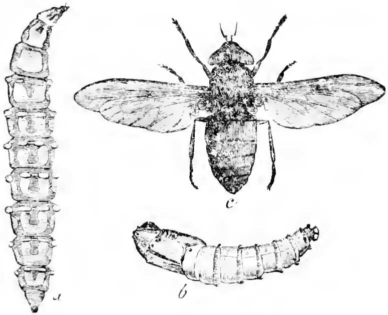


Fig. 74.—Black horse-fly, *Tabanus atratus*: *a*, larva; *b*, pupa; *c*, adult.

sive, and very little is actually known of them and their habits. The popular names are all applied to the females and are chiefly based on their habits or appearance. The "horse-flies" are among the largest of the species—some of them great massive fellows an inch or more in length; black, blue, brown or striped with yellow; sometimes covered with a bluish, whitish or golden bloom. They attack horses or cattle in their districts and so stout and short are their horny lancets that blood comes almost as they settle. High-strung, thin-skinned horses are sometimes driven frantic by the bites and by the circling of the flies seeking a place to alight, and high-bred cattle fall off seriously in fly-infested pastures.

I have referred to districts in connection with these flies and not unintentionally, because they are by no means generally distributed. Each species has its favorite haunt and cannot be found outside of it; so, in driving, one may enter a fly district and get out of it again in a few minutes. Or, after being bothered for a few minutes by a large black fly, it may be noticed that a large brown or striped one has taken its place.

The "green-heads" are usually found along the sea-shore and their name is due to the bright green eyes which cover so much of the head that nothing else is ordinarily noticed. The rest of the body is generally of some light or yellowish shade that is inconspicuous in the surroundings in which they occur.

The "golden-eyes," "deer-" or "breeze-" flies are usually inhabitants of damp woods and their names are derived partly from the golden brown mottled eyes, partly from their supposed habit and partly from their manner of attack. These are, as a rule, smaller flies and many of them have the wings barred or mottled with brown or black. The golden markings of the eyes are quite conspicuous, and it has been interestingly demonstrated that this is due to a distinct pattern for each species and that in life many forms are identifiable by this character alone.

The Tabanid larvæ so far as we know them, live in mud or at least in moist earth along the banks of streams or almost in water itself; and they feed on the minute forms of life inhabiting such places. Some occur on salt marshes, some in low meadows and some in the damp leaf mould in low woods, and this, in a measure, accounts for the local distribution of the adults: they do not get very far away from the place where they normally breed.

As a protection against these insects nettings are used on driving horses, and cattle are sometimes protected by smears of carbolated grease or fish oil. The larger horse-flies do not usually attack man, as the green-heads and deer-flies generally do. Where they are abundant enough to cause trouble, the same repellants that serve for black flies will serve against the Tabanids as well As the ground becomes better drained or cleared, so that breeding places for the larvæ are lessened in number, the adults will become gradually less troublesome; and, as a matter of fact, while the insects are sometimes horribly annoying, they are usually much fewer than they seem because of their active movements, and it may be quite possible to exterminate some of the species locally, by persistent collecting on some especially favored animal, for a few days after the flies first make their appearance.

The term "stable flies" is rather an indefinite one, but applies chiefly to one species, *Stomoxys calcitrans*, of very general distribution, in appearance like a large house fly, but with mouth parts produced so as to be capable of sucking blood. These are often present on horses and cattle in great numbers, and frequently cause great annoyance and distress. They rarely attack humans, but sometimes in hot, oppressive weather will get at exposed ankles and bite hard, usually without causing any noticeable swelling. The larvæ are maggots, like those of the common house fly, and develop in excrement, preferably in cow dung. If no better lodging is found for them, almost any kind of decaying vegetable matter will be made to answer.

A near ally to this stable fly is a somewhat smaller species known as the "horn fly" from its habit of clustering at the base of the horns of cattle. This is an importation of comparatively recent date from Mediterranean Europe, but it has spread in the few years since its arrival throughout most of the United States and into Canada. For a few years after its first appearance it produced great alarm, and weird stories were told of its destructive effect on cattle; the least of which was that the flies attacked the horns

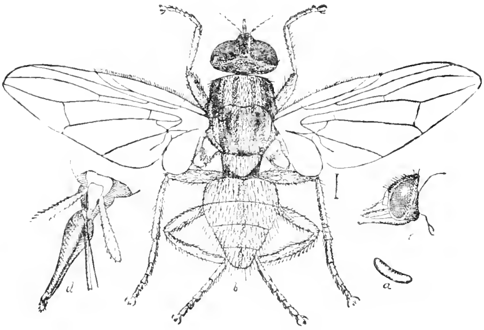

FIG. 75.—Horn fly: *a*, egg; *b*, adult; *c*, *d*, head and mouth parts.

at base, laid their eggs there, ate off the root of the horn and then penetrated the brain. As a matter of fact much injury was caused to dairies from the abundance of the flies, because they kept the cattle in a constant state of irritation and therefore poor in milk flow. But breeding was always in fresh cow manure, and at no time did the insects get within the outer surface of the animal in any stage. After two or three years of alarm it was noticed that the flies lessened in number, and finally became less abundant than the native species, which it seemed at first fated to displace.

Carbolated fish or a similar oil is used as a repellant, where flies of this character are abundant; but proper attention to the manure so as to prevent breeding is a much more effective and satisfactory measure.

Leading to those species that have been referred to as parasitic because, in the larval stage, they are confined to and dependent on the host, are a number of species that in a sense are intermediate in habit. There

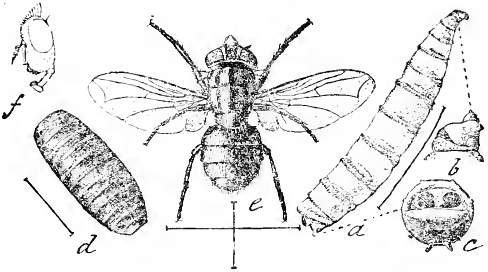


FIG. 76.—Screw-worm, *Lucilia macellaria*: *a*, *b*, *c*, larva and details; *d*, pupa, *e*, fly; *f*, its head.

are many species that are true scavengers in the larval stage; maggots which are found on exposed meats, fish or vegetable matter, and which in an almost incredibly short time dispose of most of the organic matter of an animal of even considerable size. And in the determination of what is suitable organic matter, the adult flies of some species seem to follow the rule that it is best to "blow" anything that might by any chance be suitable. Hence while the parent of the "screw-worm" normally lays her eggs in or on dead animals or on exposed meats, yet sometimes, when suitable food is scarce, she will select any raw or sore surface on even a living animal. Most of the flies of this series are attracted by foul odors which, to them, is an indication of a suitable place for eggs; hence it is not altogether unusual to have a female oviposit into the open mouth or into the nostrils of a sleeping human afflicted with catarrh or some other trouble giving rise to foul breath. Eggs of this kind are usually ready to hatch when laid and sometimes already hatched within the abdomen of the female; hence it is a matter of only a very short time for the young larva to make its way along the mucous membrane, in which it may exist for a day or two without giving rise to much discomfort. After this it bores into the soft tissue of the palate and into the cavities and sinuses of the head, giving rise to intense pain, high fever and often death, if the character of the trouble has not been at once recognized and prompt treatment made. Yet this form of parasitism is incidental or accidental, and shows principally how slight and easy is the step from the beneficial scavenger to the injurious parasite. When the eggs are deposited on or near an open wound or sore surface, the larvæ bore into the exposed tissue and feed upon the living flesh, which of course becomes much inflamed, ulcerates and attracts yet other flies of the same character, unless the matter is promptly looked after. The screw-worm flies are common enough throughout the middle, southern and central states, but are most troublesome in the south and the southwest where, during some years, much loss among domestic animals has resulted from their attacks. The adults are stout flies almost two-fifths of an inch long, metallic bluish in color, with three blackish longitudinal stripes on the upper side of the thorax.

A very similar but somewhat smaller species is the blue-bottle fly, much more common in the northern states and more metallic yellow or green in color, which has similar habits so far as attacking wounds or raw surfaces is concerned; but it does not, so far as I am aware, ever actually bore into living flesh nor into the openings of the face. The nearest approach to this was in the case of a tramp admitted to the hospital at New Brunswick, complaining of unbearable headache. Investigation showed the ear cavities filled with a dirty

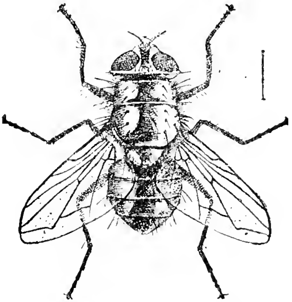

Fig. 77.—Blue-bottle fly, *Lucilia cæsar.*

mass in which were found maggots which I believe were of this species. The ears were cleaned, syringed and all the maggots removed before they had penetrated further into the head cavities.

The large blue "meat-fly" or "blow-fly" has similar habits and seems to occur all over the world, attracting attention by its large size, deep blue color and noisy hum.

The one guard against all these semiparasitic scavengers is cleanliness and disinfection. It is the attraction of foulness that brings them to the attack, and if by unavoidable accident an attack is made on some unprotected point, prompt treatment to destroy the larvæ, reduce inflammation and protect the wound, should be resorted to. Carbolated washes or ointments are excellent as protectives, and nothing is better than peroxide of hydrogen to clean and sterilize a suppurating sore.

It is rather an easy step from the sort of elementary parasitism just described, to the simpler forms of attack by bot-flies, or *Œstridæ*. Bot-flies in the adult stage are usually large, stout species with a large head, but no functional mouth parts. The adults, therefore, though very highly specialized in some directions, are merely produced to provide for the continuance of the species; incapable of harm in themselves and, so far as we know, not productive of any distinct good.

Fig. 78.—Blow-fly, *Calliphora vomitoria*.

In the simplest forms the adult fly lays an egg on the skin of the animal that serves as a host; the larva hatches, bores its way through the skin, enters the tissue and lodges. It increases in size, sometimes forms a swelling which may or may not suppurate, and, when full grown, works out through the skin, drops to the ground which it enters to pupate, develops to an adult in due course and the cycle is complete. Bots of this character attack a great variety of animals and even man is not exempt from them. I have personal knowledge of such a case and there are enough others on record to make it quite certain that under abnormal conditions some of the species that ordinarily attack other animals may attack man. In tropical regions the attacks on man are much more frequent and are referred to species of *Dermatobia*. So far as I am aware no species has been demonstrated that is confined to human beings.

Almost any part of the animal body may be attacked by bots; but in a general way they are most likely to appear in regions which the host is least able to reach with its teeth, *e.g.*, the neck; but they occur often enough in other portions of the body. Occa-

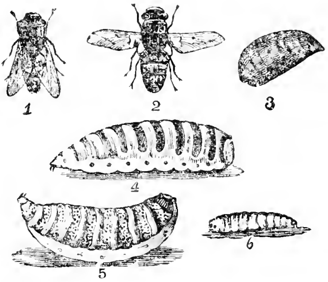


FIG. 79.—The sheep bot, *Œstrus ovis:* 1, 2, flies; 3, pupa; 4, 5, full-grown larvæ; 6, young larva.

sionally they appear to attack specific organs as those that destroy the testes of squirrels and chipmunks, or to be confined to special regions like those that are so often found around the anal openings of hares and rabbits.

Some species have almost identically the habits that were observed in the screw-worms entering the head of man through the nostrils. An example of this is the well-known sheep bot, the adult of which lays its eggs ready to hatch or just hatched on the mucus of the nostrils of the sheep. The larvæ work their way up into the head passages, feeding on the mucus, on the membrane itself and, if pressed for food, upon the muscular tissue. When the infestation is a bad one they work their way, through all the openings between or in the bones, to all parts of the head cavity, and into the brain itself, in such cases causing "staggers" and death. The larvæ like almost all bots are set with short stiff spines, definitely arranged, that enable them to make their way forward, and there is also a pair of mouth hooks that enables the grub to fasten itself firmly to any place selected. This spiny structure and the definite mouth hooks are not developed in the "screw-worm," which is a typical maggot, altogether unlike the highly developed "bot." The amount of damage caused by the sheep bot is very great in many localities, while in others the species seems to be altogether unknown. As to remedies against them, each locality or herdsman has its or his own, and none is entirely satisfactory.

An altogether different type of bot is that which occurs in horses. The fly that produces this has rather a conical pointed abdomen and a brown hairy body. The eggs are laid on and attached to the hair, usually on the forelegs or on some part easily reached by the horse with its head; and they remain there, unhatched, although the embryo may be fully developed, until the horse in licking itself or a companion dislodges the egg-cap and, freeing the larva, transfers it to the mucous membrane of the mouth. From this place it moves at once and makes its way down the œsophagus into the stomach. Here the young bot finds its proper conditions and becomes anchored by means of a pair of mouth hooks into the lining membrane. It feeds here, absorbing the juices for several months, maturing in late spring, and then loosens its hold, is carried into the intestines with the excrement and so on through the anus. When it reaches the ground it burrows into it at once, changes to a pupa, and not until a month thereafter does it transform into an adult fly. A full year is thus required for the development of the species, and there is only one danger season for infection—the period during July and August when the flies are on the wing.

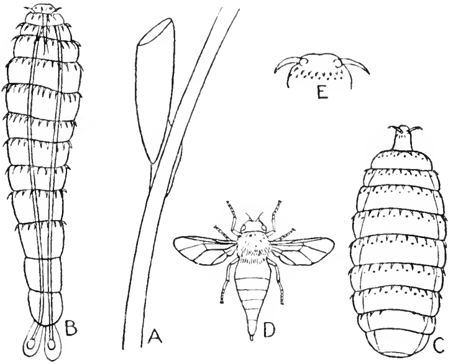


FIG. 80.—The horse bot, *Gastrophilus equi*: *a*, egg, attached to hair; *b*, young; *c*, full-grown larva; *d*, adult fly; *e*, hooks of larva.

A few bots, while not of course an advantage, will not hurt a horse. More than a few will cause trouble, in proportion to the amount of infestation. There is, naturally, the irritation to the membrane to which the insects are attached, causing digestive derangement; there is also the positive drain upon the system by the feeding maggot which is apt to weaken the animal and to intensify the effect of the digestive trouble; and finally, when there are many bots, they tend to form a mechanical obstruction to the passage of food from the stomach to the intestine. A bad infestation is a serious matter and may easily become fatal.

On well-cared-for horses bots are not often troublesome. The eggs are readily seen and as they cannot be hatched for several days after being deposited, they may be easily removed when the animal is groomed. They are firmly enough attached, however, not to be easily removable by the horse, and the embryo develops within ten days after they are laid. If at any time after that the egg is licked, the cap covering the top opens and the larva slips out of the shell on to the tongue, moving actively at once toward the gullet. A thorough brushing and washing once every week will therefore be sufficient to keep a horse free, even when exposed to the attacks of the flies.

It is curious to note how all animals subject to bots appear to dread the adult flies. They cannot possibly know the relationship between the flies and the bots, and it is probably the apparent intention to attack that arouses the fear that undoubtedly exists.

Horned cattle are subject to the attacks of bots that form swellings or "warbles" under the skin, usually on each side of the backbone; and these insects affect not only the general health of the animal, but very materially reduce the value of its hide. In fact the impairment of value so caused has been reckoned at many millions annually while the impairment in value of dairy products, due to the poor condition of suffering cows, can hardly be estimated.

The life cycle of this species is also interesting and, in a way, decidedly more complicated than that of any of the species previously referred to. The adult is not so unlike that of the horse bot; a little more compactly built, with a shorter abdomen and a somewhat banded appearance in black and whitish. Like its ally it lays its eggs on the hair of the animal it infests, and here also further development is dependent upon the introduction of the young larva into the mouth. But there the resemblance ceases, for the young larva, instead of permitting itself to be carried to the stomach, attaches itself to the walls of the œsophagus and bores its way through into the muscular tissue, continuing on until it reaches the desired position beneath the skin.

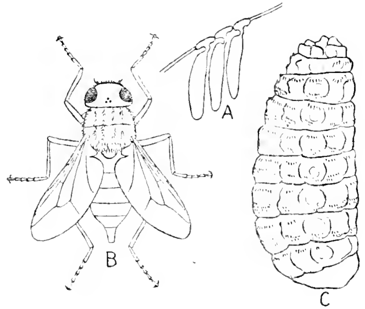


FIG. 81.—The ox bot, *Hypoderma lineata*: *a*, eggs attached to hair; *b*, fly; *c*, larva.

As with the horse, the well-cared-for dairy animal rarely suffers from bots; the eggs are so conspicuous that they readily attract attention, and removal is easy. If any do escape and bot-swellings are noticed, they should be lanced and the contained larva removed. Cattle on the range or beef cattle in pasture suffer much more, because they are less or not at all looked after, and the bots are not suspected until the ulcerating sores attract attention.

A still more highly specialized type is represented by the "louse flies," sometimes separated under the term *Pupipara*, or those that give birth to pupæ. They are usually active, flattened, brown or yellow flies, with small head and rounded abdomen. Some of them, infesting birds of prey, fly actively, while others, like the "sheep tick," are wingless, although not therefore inactive. They are called pupipara because the egg hatches within the body of the female and the larva attains its entire growth before being extruded, ready to pupate. Of course this means a very slow rate of reproduction, since the number of young matured

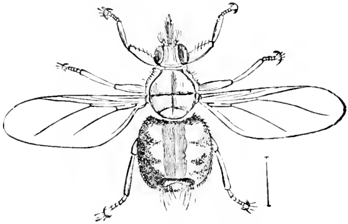

Fig. 82.—A louse fly, *Olfersia species*.

at one time cannot be great; but, on the other hand, it is also a safe rate, because the larvæ run few dangers during their early life, and the infant mortality is not very high. Nestlings become infested from the mother bird, and the flies are quite active enough to make short flights from the host and back again when necessary to escape an especially vigorous hunt. When the host dies or is killed the parasites leave it at once, and seek shelter on any living thing in the vicinity.

"Sheep ticks" which, as already indicated, are wingless, do really look very much more like ticks than like flies; their long mouth parts, small thorax, long legs and round flattened abdomen giving them a peculiarly spider-like appearance. They are sometimes very abundant on sheep, and find no difficulty in getting on to new animals because of the habit of congregating into dense masses, peculiar to their host. The body of these flies is very tough and leathery, and I am informed by those who handle the raw hides that they will survive all the preliminary handlings, cleaning and soakings which the pelts undergo before being denuded of wool and prepared for tanning. Herders know of a great variety of "dips" useful

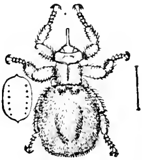

FIG. 83.—Sheep tick, *Melophagus ovinus*.

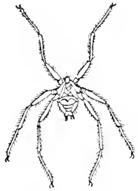

FIG. 84.—A bat tick, *Nycteribia*.

against these insects and "dipping" is a regular practice wherever sheep are raised in any numbers.

The extreme development in this direction we find in the bat ticks, which are even more spider-like than the sheep tick and have similar habits, while infesting a much-shorter-haired animal. It is distinctly curious that while there are many species of these louse flies among birds, there are only a few, very aberrant forms, that have adapted themselves to live on four-footed animals.

We find, then, that among the insects there are foes to almost all kinds of vertebrates and that they are not at all despicable foes. While the death of the animal attacked is never sought as a prime object, it not infrequently follows as the result, and it is not by any means easy, even for man himself, to guard against injury in all cases.

We see also that parasitism is not by any means a primitive condition but an adaptation, frequently accompanied by specialization of a high order. It is, in some of its manifestations, of comparatively recent origin, the greatest diversities obtaining in the highly specialized *Diptera*, while the simple forms are all in the more generalized orders, being there little more than an adaptation to life on an animal rather than on a plant.

# CHAPTER VIII

## THEIR RELATION TO MAN AS BENEFACTORS

Insects as benefactors to the human race have been very little considered, their position on the opposite side having been so much more emphasized; and yet, if some few species were eliminated, their absence would be very seriously felt for a time, until a substitute for them could be discovered. Possibly the reference to them as benefactors is a little inaccurate for most of those referred to here—they are useful to man rather than his benefactors. We might, of course, class as benefactors those that pollenize his fruits and other crops; but there the benefit is indirect as to man, and more direct as to the plants, hence coming under another head.

Directly beneficial to man are those insects that act as scavengers, working to reduce to their original inorganic compounds those animal and vegetable materials that are dead or dying and of no further use as living organisms. The extent of the benefit thus derived is absolutely unappreciated; but were all insect scavengers removed at one time and all dead animal and vegetable material left to other decays, the foulness and noxious odors that would be thus let loose are beyond all description.

Does a small animal die in the field—within a few hours burying beetles are working to get it underground; flies have laid their eggs on the body and numerous other species have begun feeding on the skin, the hair and the flesh. Within twenty-four hours in summer, the process of disintegration is well under way and in a remarkably short time nothing but the bony framework remains.

Hardly has a cow dropped a mass of excrement in the pasture, before it is covered with flies absorbing the moisture, helping to form a dry outer coating and ovipositing for maggots to help reduce the half-decayed mass into fragments that may be mingled with or absorbed by the soil. If, after a dropping has been in the field forty-eight hours, it is broken up in a pail of water, the number of specimens and species that will come to the surface is startling.

Is a forest giant stricken and borne to the ground by wind, flood or lightning—immediately insects of many sorts attack and begin to reduce it to dust, continuing their work until nothing remains. And so of all organic matter in which life is waning or from which it has departed—such matter is prey to insects and they are never backward in fulfilling their duty.

This scavenger function is by no means a "low," or "primitive" habit; it does not exist in the lowest orders at all and is best developed in the *Coleoptera* and *Diptera*, which are among the highly specialized and dominant types. To be sure the *Thysanura* are largely feeders on the products of decay and hence may seem to be entitled to rank as scavengers; but they rather come after decay and feed on its products, hence their presence is merely indicative of moisture and decay produced by other causes.

The *Termites* among the Neuropterous orders are feeders on wood and other vegetable products, but they invade rather for building purposes and are never found in really decaying material.

The order *Hemiptera* contains no scavengers among either the *Homoptera* or *Heteroptera* and stands entirely free from even a tendency in that direction.

In the *Coleoptera* or beetles there are several families that are scavengers in whole or in part, and some of these families contain very large numbers of species. In a very general way the scavengers may be recognized by the clavate or club-shaped antennæ, combined with five-jointed feet or tarsi, and thus belonging to the series "*Clavicornia.*"

The *Staphylinidæ* or rove-beetles are found wherever decaying or fermenting material occurs, although by no means all the Staphylinids are scavengers. They are long, slender, somewhat flattened beetles, with wing-covers or elytra extending over only two segments of the abdomen. The other segments are free and flexible, often readily up-curved so that it sometimes appears as if they intended to sting. Some of these species are so small and slender that they are difficult to see and some are of considerable size; sometimes they are smooth and shining and sometimes densely covered with short silky pile, both methods serving to keep the insects clean in their often unsavory surroundings. As an indication of their habits some of the species have peculiarly sickening odors that in penetration and volume are altogether out of proportion to the size of the insect producing them. In animal or vegetable decay, in excrement, under and in dead animals, in the fermenting sap of injured or dying trees, in fungi of all kinds—in all these places our Staphylinids occur and everywhere do their share of the needed work.

Closely allied to them come several families of minute beetles, some of them of odd and bizarre shapes; all of them with the enlargement or club of the antenna well marked, and all of them feeders on dead or decaying matter. Their names alone would tell us nothing; to go into their habits and peculiarities would require another book, for there are literally hundreds of them.

Conspicuous in appearance and habit are the burying beetles and carrion beetles, their names indicative of their functions. They are often of moderate or large size and at the end of the feelers the club is capitate or shaped like a head, an arrangement that permits the organization of an extremely sensitive olfactory system. The sense of smell in these insects is so well developed indeed, that even a small dead animal is unerringly located very soon after its demise. I have seen these beetles climb to the tip of a twig, extend the antennæ in every direction with the leaves of the tip widely separated, and then fly in a straight line and without hesitation in the direction from which, apparently, an agreeable odor was perceived. The burying beetles are so called because of their habit of digging out the soil from beneath a small animal until it sinks down to or below the level of the ground, and the powerful head, thorax and legs are well adapted for this kind of work. The carrion beetles are quite as prompt in their arrival, but do not work in the same way. They are content with ovipositing on or under the cadaver, trusting the resulting larvæ to their own devices. And what a lot and variety of these carrion beetles there are! Species so small as to be almost invisible to the unaided eye, and others an inch or more in length. Species smooth and shining so that none of the material in which they live can adhere to them, and species covered with fine

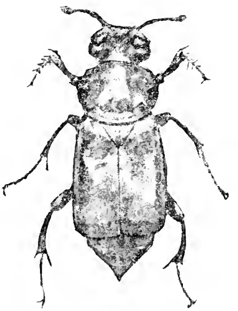

FIG. 85.—A burying beetle, *Necrophorus americanus*.

silky pubescence, or rough and ridged for the lodgment of any sort of material, serving in some cases to disguise and conceal. And as with most of the scavenger families, not all of the species are confined to animal foods. Some are found in decaying vegetation, and yet more in fungi, which harbor a great number of species.

The *Histeridæ* or "pill beetles" are little, chunky creatures shining black or metallic in appearance, and the legs all broad and flattened, fitted for digging. They occur in decays and ferments of all kinds, but their habits are more diverse than in some of the other groups, predatory forms being not uncommon.

And then come those species allied to the *Dermestidæ* or larder beetles; species that feed upon dead organic material but which instead of being advantageous are rather the reverse, since they often feed upon material that man desires for his own use, like dried and smoked meats, hides and even the animal fabrics. Here again we note that the matter of usefulness is after all only a relative one, since the very function that makes a species valuable when it affects something of no use to man, makes it harmful when it affects something that he wishes to keep.

There are exceptional scavengers in most of the other beetle families, but none that need mention here except the "tumble-bugs" and their allies, which feed on excrementitious material, often rolling large balls of dung from the place where it was found to a place where it can be conveniently buried to serve as food for their larvæ. These tumble-bugs are members of the Lamellicorn series which contains mostly plant feeders and which are more fully referred to as plant enemies.

The *Lepidoptera* contain no scavengers strictly speaking, although there are some species that feed on dried organic matter, animal as well as vegetable, and in the *Hymenoptera* only the ants may be classed as such. Ants, of course, are feeders on a very great variety of materials. Some species will attack and devour any living thing that comes in their way; others

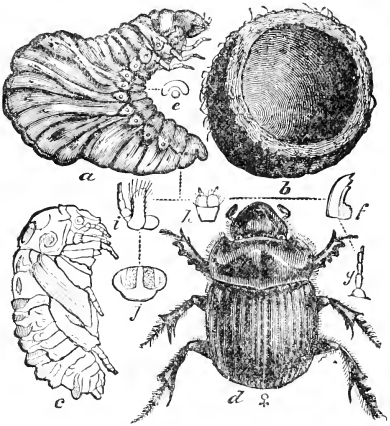


FIG. 86.—A "tumble-bug," *Copris carolina: a*, larva; *b*, the cell in which it lived; *c*, pupa; *d*, female beetle.

confine themselves to vegetable food only and yet others seem to be restricted to liquid food. Most of them have quite a range of supplies and some species may be found almost anywhere, even in our houses. And yet ants are rarely thought of as real scavengers, for they are not seen in or on decaying animals or in or on foul excrements.

In the *Diptera*, however, we have scavengers in great number and variety; and yet very much alike after all, for in the larval stage they are nearly all maggots, similar to those of the common house fly. Wherever an animal dies, a mass of excrement drops in the field, an over-ripe fruit falls to the ground or a pail of garbage is set outdoors, there we find flies present at once and in a few hours young maggots. It has been said that flies will devour an ox more rapidly than a lion and while that may be a little exaggerated, they will certainly make a more complete job of it. It is literally

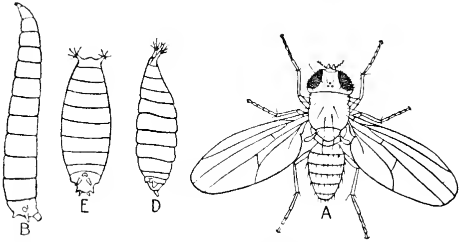


FIG. 87.—Pommace fly; *Drosophila ampelophila: a*, adult; *b*, larva; *d*, *e*, pupa.

astounding to note how rapidly a small carcass may be transformed into a mass of squirming maggots, apparently liquefying the tissues so that they may be absorbed through the small mouth orifice. And it needs so little to attract these flies. Lay out a few bruised apples, pears or other fruit on a table, and in a short time they will be covered with little yellowish or gray flies having bright, brick-red eyes—pommace flies—coming from no one knows where, but attracted by the odor of the ferment. In the fall when cider or wine is making, every tub or barrel of must is an attraction, and in the ferment thrown out of the bung of the wine cask the larvæ occur by the hundred. Not long as larvæ either, for in two or three days they have become full-grown, change to a pupa and then to the adult condition. And so we find that in this, the most highly organized series of insects, scavengers are numerous and effective. So effective, indeed, that their usefulness is not recognized by the average man, because he has no chance of knowing what conditions would otherwise be.

Among the insects of direct use to man none are of greater importance than the silk-worms. Silk is in such general, almost universal, use, that there is scarcely a moderately well-dressed individual of either sex that does not have some of it as part of a garment or other article of wear. Of the millions who wear or use silk how many ever know, or knowing, realize, that every particle of that silk is the product of a caterpillar; nothing more than a dried viscid salivary secretion, originally intended by nature as a covering to protect the pupal stage of the insect? This covering or case is called a cocoon, and cocoons are spun by many caterpillars, some of them much larger than the Chinese silk-worm.

Why, then, if there are many silk spinners do we use one only, and what particular advantage has the silk of this species over all others? As to the latter, it has few advantages over other caterpillar silks: it is not nearly so strong as some produced by other varieties, it is not more lustrous, and it is not nearly so great in quantity. Its one great advantage for our use is that it can be more easily reeled than any other known variety. The silk-worm, when ready to make its cocoon, spins a small quantity of loose supporting threads or floss and then starts inside this framework, spinning with a continuous thread, unless interrupted, until the entire cocoon is completed—a thread almost a mile long which, under favorable conditions, can be unwound in the same way and without a break! Generally, other caterpillars that spin cocoons do not work continuously; or if they do work steadily on, they make a patchwork affair of it. They may spin a few yards at one end, break the thread, put in a few yards at an-

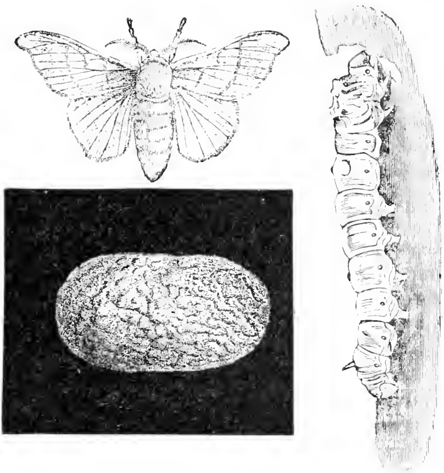

FIG. 88.—Silk-worm, cocoon and male moth.

other point, and so on until the work is completed, making a nice even job when everything is done, but a cocoon that cannot be profitably unwound or reeled because of the great number of breaks.

Then, too, the particular species, *Sericaria mori*, has been domesticated so long that it has developed some highly desirable qualities. The adult moths are very sluggish, even the males flying little or not at all, while the females are practically incapable of flight. They pair readily in confinement, are hardy, and very fecund, the female producing several hundred eggs. All these advantages, together with the ease of handling the caterpillars, are matters in favor of the *mori*, and its propagation is largely the work of women and children who do it as a side issue and hence very cheaply. It is this latter factor indeed that has barred silk culture in America, where the cost of labor is too high to make the venture attractive to any class.

It has already been said that the silk is in the nature of a salivary secretion; but that is only partly true,

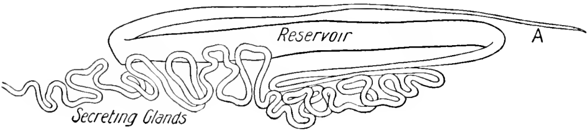


Fig. 89.—Salivary gland of silk-worm.

because, although the material is secreted by one pair of what are usually salivary glands, these glands have been so enormously enlarged that they extend along the sides of the body for almost the full length of the caterpillar, and the material has become so sticky and viscid that it could not possibly have any digestive function. The two glands unite into a single outlet on the lower lip of the caterpillar, and as soon as the fine thread of liquid issues from the opening of the spinning organ and comes into contact with the air, it hardens sufficiently to hold its form, reaching its full strength and elasticity a few moments later. As to the value of silk products each year, they must be figured in millions of dollars, so that the humble caterpillar adds not a little to the wealth of the producing countries, and to the support of those engaged in textile industries. The elimination of the silk-worm and its product, while it would not eventually cause mankind any serious inconvenience, would deprive it, for all time, of one of its most valued and widely employed fabrics.

Next in order of value are the bees and bee-products which seem to have been recognized and employed almost or quite as long as we have any historic records. Honey from wild bees is known to every savage nation and has formed an important item of food. And not of food alone, for away back in the dark ages it was found that it made an excellent drink when fermented, the "meth" of the ancient Saxons being the ancestor of the "metheglin" of more recent times. The latter drink is little known now-a-days, especially in cities and towns where malted and distilled liquors are in use; but it has still a vogue in a few sections of the country, where those who first make its acquaintance gain a wholesome respect for those ancestors of ours whose capacity for it was measured by "flagons," or "horns."

Wax and honey as products of the bee are universally known and the organization of the beehive is so well understood that it need only be referred to. Paraffine has largely supplanted beeswax for many purposes, while sugar and glucose have replaced honey; so, even were the bee now completely eliminated from our fauna, mankind would still worry along. Nevertheless, bee-products are on the increase rather than otherwise and there is no lessening in the demand for them.

The products of the "lac" insects known as "stick lac," "shell-lac," etc., are yet of considerable importance although the insect "lac" has now been largely replaced by cheaper preparations from other sources, for general use. The lac insect is really one of the "soft scales," allied to the most serious of our tree pests: indeed it is a tree pest, tolerated only because the insect is of more value to us than the plant upon which it feeds. Infested twigs are cut and stored when the insect has reached the proper stage, and the adherent scales and their secretions are dissolved off when they are to be commercially used. Lac is a product of the Orient and many of the fine polishes and lacquers of Indian, Chinese and Japanese workmen are based upon it. There are allied species of *Coccidæ* occurring in tropical America; but none that have been made commercially useful.

Cochineal as a source of a beautiful crimson and scarlet is well known and is also a scale insect or *Coccus*, belonging to the mealy-bug series. It infests certain kinds of cacti and is cultivated in plantations called "nopalries." It is the source of the coloring matter known as crimson lake, and is a native of Mexico and Central America. Before the day of aniline colors cochineal was extremely valuable and important; but at present the complete elimination of the insect would cause little if any inconvenience.

It is noticeable that, except in the case of silk, we have substitutes for practically all the insect products and even silk has been artificially produced, *i.e.*, a product so closely resembling it as to be called artificial silk has been made that could be developed practically in case of necessity.

In olden days insects had a wider use, and out of a plague a food supply was sometimes developed. "Locusts" or grasshoppers as articles of food are known among barbarous nations of many countries where the insects are sufficiently abundant. The Indians of the Rocky Mountain regions in America and the aborigines of Africa were equally familiar with a grass-hopper diet and with the methods of preparing them.

It has even been suggested that there is no reason why they should not be retained on our modern bills of fare, and experiments have been made in different methods of preparation. Fried they are said to have a sweet, nutty flavor, while in a stew with milk they recall oysters. It must be confessed that no very great enthusiasm has ever been developed for this kind of diet, and on the whole the use of grasshoppers for food purposes is distinctly on the wane.

In South America a species of water bug of the *Corixa* series occurs in great abundance in some localities and lays its eggs in large numbers on the surface among the sedges. These eggs are gathered, dried and preserved by the natives, who mash and bake them into a cake that is much appreciated. Inasmuch as the eggs have a very decided bed-buggy odor, it would require considerable education to make that sort of omelet popular.

The large boring larvæ of *Coleoptera* and even some *Lepidoptera* are not unusual articles of food in tropical countries, and ants or ant larvæ and pupæ have also served as sources of food supply to uncivilized man; but as civilization tends to eliminate the insects in its advance, their decreased numbers would render them less available as sources of supply even were better or more usual articles not more plentiful.

Galls as sources of supply for tannic acid are still gathered in some localities, and some forests are commercially profitable as gall producers. When inks were largely dependent upon galls for their black color, there was a greater demand for them than now, when chemistry supplies other if not better sources of more or less permanent black stains.

Insects have from time to time served as ingredients in medicaments; but very few are so used at the present time. Of these the *Cantharides* or blister beetles are best known and yet most widely employed. In the body juices there is secreted an extremely irritating material known as cantharidin which, when applied to the skin, produces blisters or, taken internally, produces inflammatory conditions of the genito-urinary system. Most of the blister beetles possess this property to some extent, and a fresh specimen of any of the common American species crushed upon the skin will produce blisters; but the officinal preparations are obtained from a European species, known as the

FIG. 90.—Spanish flies, *Lytta vesicatoria.*

Spanish fly, *Lytta vesicatoria*, from the locality whence most of the specimens come and from its vesicating properties. These beetles come in great swarms when they emerge and are on the wing for a few days only, during which period the entire country is engaged in gathering them in sheets on which they are killed and dried, after which they may be preserved indefinitely. The blistering property is dissolved out of the powdered beetles with alcohol.

Broadly stated there are no insects that are indispensable to man; there are a few that are very useful to him, aside from those that are plant pollinators, and he makes use of a few others for which he has substitute materials at hand and already in partial use.

# CHAPTER IX

## THEIR RELATION TO MAN: AS CARRIERS OF DISEASES

SINCE the development and general acceptance of the microbian or "germ" theory as applied to many contagious and infectious diseases, and its absolute demonstration in plagues like cholera, typhoid fever, dysentery and other enteric or intestinal troubles, as well as in consumption, pneumonia, diphtheria and other affections of the respiratory organs, the question of the agencies concerned in the distribution of these germs has come to the front.

The surgeon has long known that suppurations and pus-producing inflammations might be carried from one individual to another by almost any sort of carrier; so when he operates, he sterilizes his instruments, his hands, the cut or bruised surfaces, and protects the wounds by antiseptic dressings. That flies were among the agencies for spreading suppurations was soon learned, and the readiness with which flies gather on sores or raw surfaces is matter of common observation. When it was observed that flies of various kinds gathered with as much readiness on fecal or excrementitious matters as on food products in the kitchen, and were ready to change their diet from one to the other without much provocation, the conclusion that they might inoculate the food products and through them healthy individuals from the fecal matter was not a difficult one to draw.

In the cholera epidemic at Hamburg not so many years ago, this was absolutely demonstrated as to that disease. It remained for the United States, during its war with Spain, to demonstrate with equal positiveness that typhoid and other enteric fevers could be carried in the same way. More soldiers killed by common house flies than by Spanish bullets, is the unenviable record, and the most unsafe places for our soldiers were the fly-infested home camps where open latrines and near-by mess tents furnished ideal conditions—for the flies and the diseases.

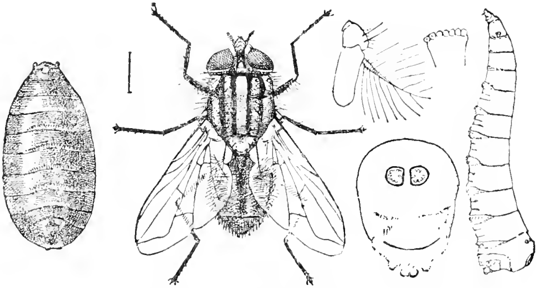

Fig. 91.—The house fly, *Musca domestica:* larva with details at right, puparium at left.

While flies are not the only carriers of enteric disease germs and these do not actually depend upon insects as their sole means of spread, yet the habits and structures of flies are peculiarly adapted for effective service of this nature and they are correspondingly dangerous. No other insects live in such close communion with man, and so much are they regarded as a matter of course that their companionship at our table arouses no fear; and such is their persistence that they gain admittance to the palace of royalty, as well as the hovel of the peasant. They breed in all sorts of decaying and excrementitious matter, in garbage pails and even in neglected corners of cellar or store-room; a very little material serving to mature a large number of specimens. The common house fly, *Musca domestica*, prefers horse-manure for its development and is most numerous in the vicinity of stables. The eggs are laid in little masses by the adults,

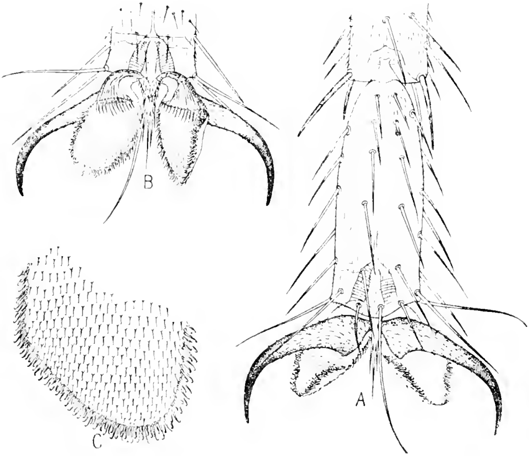


Fig. 92.—Foot of the house fly: *a*, the last tarsal joint and claws; *b*, claws and pulvilli; *c*, a small section of the pulvillus, showing hooked hairs.

the larvæ or maggots hatch almost at once, and a week later these are full grown and ready to transform.

On the soles of their feet flies have pads of very fine hair, which serve excellently as gatherers of micro-organisms from the surfaces over which they travel, and equally well as distributors on others over which they may track later. This point has been proved experimentally by allowing flies to walk over cholera excretions, and afterward over plates of prepared gelatin. In the incubator, every footprint developed a flourishing colony of virulent cholera germs.

The mouth parts of flies are almost equally well adapted for similar purposes. At the end of the fleshy lips are lobe-like expansions furnished with chitinous ridges by means of which the pasty masses of food are scraped into shape to be ingested by the insect. These

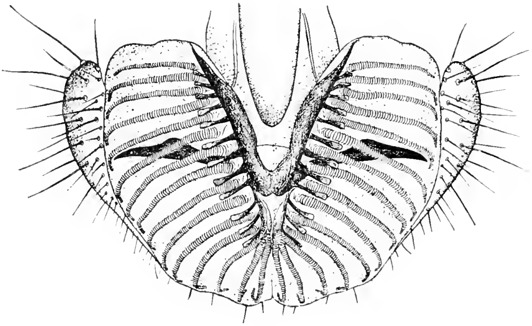

FIG. 93.—Lapping organ at the tip of the fly mouth.

ridges are excellent resting places for the minute organisms and, when the flies change their diet, the germs are directly inoculated into the new food material, whatever its character. And flies are not always cleanly in their habits, but void their excrement anywhere in small, pasty masses which dry quickly. It has been shown that the bacilli of intestinal troubles pass through the digestive tract of the insect unchanged, hence every "fly speck" may be a source of danger.

This method of transfer for pathogenic organisms is very simple and direct, and is applicable only to forms that undergo no change and which, when implanted in a suitable medium, will continue their growth and increase with unabated virulence. We have yet quite a different class of diseases, also due to microscopic organisms, but of an altogether different type: minute, single celled animals in fact, that live in special body- or blood-cells, but are not capable of completing their entire life cycle in a single host.

The best known example of this sort of infestation is that due to the *Plasmodium* parasite which produces what is loosely known as malaria. It is not so long ago that almost any sort of indefinite illness was likely to be classed as a "touch of malaria:" now-a-days when a doctor diagnoses "malaria" he refers to an affection caused by one of two or three specific organisms that have very definite life cycles and produce very definite results. All of them agree in being *Sporozoa*, *i.e.*, animals that reproduce by means of spores, and in that they do not complete their entire life cycle within the body of their human host. The parasite producing the ordinary type of tertian malaria or "chills and fever" lives in the red blood-corpuscles of the human body and comes to maturity in such a blood-cell in forty-eight hours. It then breaks up into a mass of minute spores which rupture the cell and are liberated into the blood-serum. In this they float about for a short time, and then each spore makes its way into a sound red blood-corpuscle, and in forty-eight hours is itself mature and in turn reproduces in the same way. As all the parasites come to maturity and liberate their spores at about the same time, this causes a disturbance of the body temperature resulting in a chill, followed by a fever when the

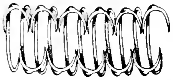

FIG. 94.—Part of one of the pseudo-trachea used as scraping organ.

spores are entering new blood-corpuscles. In other words the "chills" and "fever" merely emphasize the period at which the parasite sporulates, and the ill effects of malaria are due to the gradual destruction of the red blood-cells.

If some of this infested blood be drawn from a patient and injected into the circulation of a healthy individual, a new case of malaria will result; but in no other way can there be a direct infection from one individual to another. Normally this reproduction by means of spores continues in an infested individual for some time and then, in addition to the spores, special cells develop which, when liberated into the blood-serum, make no attempt to enter new blood-corpuscles. These are the "gametes," of two types, differing a little in size and form and termed respectively "micro-" and "macro-gametes." They undergo no change in the human body and may remain in that stage for an indefinite period, even when the active reproduction of the *Plasmodia* has been checked and the patient is apparently well. Taken from the human body by any sort of blood-sucker or even drawn on a properly prepared slide, further development takes place. From the microgametes slender, whip-like processes are produced, known as "flagellæ," and these break off and represent the male element that unites or conjugates with the large unaltered "macrogamete" representing the female element. At this point development stops unless the blood is in the stomach of a mosquito belonging to the genus *Anopheles*. If it is not only *Anopheles*, but a member of the right species, the conjugated gamete elongates and becomes a "vermicule" which bores into the tissue of the mosquito stomach, increases in size and gradually works its way to the outer surface where it forms a little lump or protuberance, now known as a "zygote." In about ten days this form matures and bursts, liberating thousands of "blasts" or "sporozoits" into the body cavity of the mosquito. In

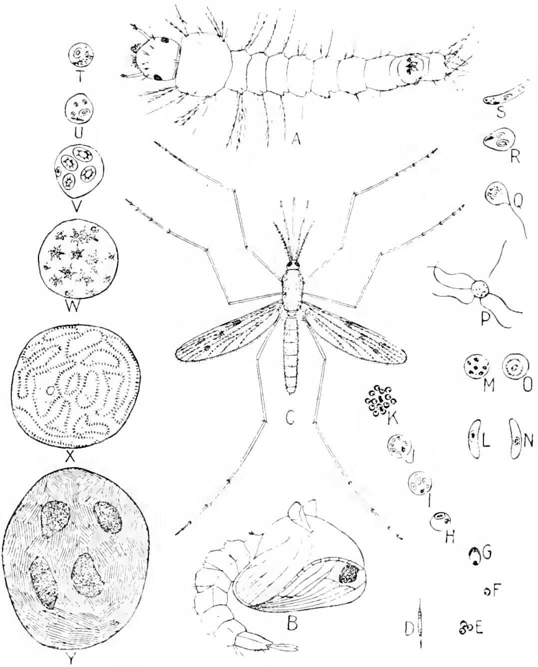


FIG. 95.—Anopheles and Malaria: *a*, larva; *b*, pupa; *c*, adult; *d*, the blast introduced into the blood by the mosquito; *e* to *j*, stages through which the Plasmodium passes in the red blood-corpuscle; *k*, the spores which enter new blood-corpuscles; *l*, *m*, the microgamete; *n*, *o*, the macrogamete; *p*, flagellæ forming; *q*, union of a flagellum with macrogamete; *r*, fusion of nuclei; *s*, the vermicule; *t* to *y*, formation of the zygote in the mosquito stomach; the fully developed zygote, *y*, rupturing to produce blasts *d*.

some way these gather into the salivary glands, and when that mosquito bites again, it introduces with its droplet of saliva a large number of "sporozoits" which, if they find conditions favorable, enter red blood-corpuscles and set up a case of malaria.

The transmission of this disease, then, is by no means a simple matter, and the proper species of *Anopheles* is absolutely essential to it. The elimination of these mosquitoes from any locality would carry with it the elimination of malarial troubles as well. It may be interesting to note in this connection that the species of *Anopheles* live easily in settled communities, enter houses freely where they can manage it, and that the female passes the winter in the adult stage in cellars, coming up occasionally into well-warmed rooms and even biting. Normally, they do not become active until well along in May or in June, when eggs are laid by the female which has been fertilized the previous fall.

All stages of the parasites causing the various forms of malaria have been followed in both man and the mosquito, and no part of the history above given is guess-work. The connection between the *Stegomyia* mosquito and yellow-fever is equally certain, though the specific parasite has never been made out in either man or insect. Direct experiment has furnished convincing proof of the connection, and the treatment of yellow-fever epidemics has entered a new phase. The efficient work done in the Panama Canal Zone has demonstrated that the disease is quite controllable through the insect and, incidentally, collections made by entomologists from the U. S. Department of Agriculture at Washington, have shown that this *Stegomyia* is never found away from human settlements. The relation, then, is extremely close between this insect and man, and they are both needful to the continued existence of the disease.

There are other tropical fevers that are probably as much dependent upon other mosquitoes, but we know less about them. We do know that several forms of bird malaria, due to species of *Proteosoma*, are also dependent upon mosquitoes as intermediate hosts, and

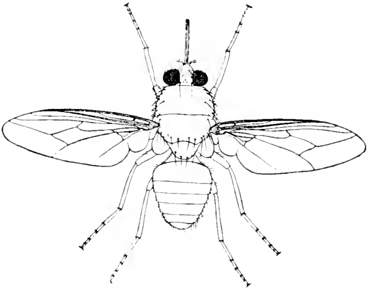

FIG. 96.—The Tsetse-fly, *Glossina morsitans*.

how many diseases of other animals are transmitted by them is as yet matter of conjecture only.

A species of *Culex* very closely allied to our common "house" or "rain-barrel" pest is responsible for the transmission of that tropical disease "filariasis" which sometimes causes the abnormal enlargement of the lymphatics and thickening of the skin, known as "elephantiasis." Other species have been charged with being agents in the transmission of leprosy, but this must be considered "not proven" as yet.

In all these cases, the mosquito is an intermediate host: not a mere carrier, but a fellow sufferer with man, subject to another form of the same disease, and in this respect there is a fundamental difference from those troubles conveyed by house flies, which suffer nothing, and are purely mechanical transporters of the infection—albeit peculiarly well adapted for their purpose.

There are other flies, however, that seem to be nearer the mosquitoes in this respect and, among these, are the species of *Glossina* or "tsetse" flies of South Africa, which are known to produce fatal affections in horses and have been recently charged with being agents in the transmission of the "sleeping sickness."

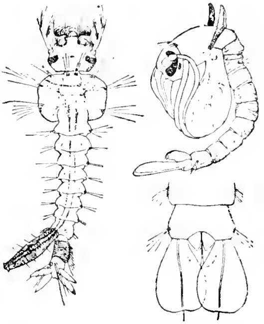

FIG. 97.—Larva and pupa of the house mosquito.

All mosquitoes pass their early or larval stages in water, and that is about the only feature that is common to all of them. They differ widely in the character of the waters which they inhabit, in the period of development, and in the number of broods. Some pass the winter in the egg state, some as larvæ and a very fair proportion as adults. All the species that are closely associated with man may breed in dirty water, and some in such as is absolutely filthy.

*Culex pipiens*, the common "house mosquito," breeds in rain barrels, lot puddles, cess-pools, gutters and sewer basins. It is rarely found in clean water and almost never in streams or brooks. The eggs are laid in a mass or raft on the surface and are easily seen when their character has once been recognized. In forty-eight hours the larva is ready to hatch, a little lid drops from that surface of the egg that rests upon the water, and the minute wriggler slides at once into its natural element. This "wriggler" is so named from its peculiar jerky mode of progression. It has, attached to its mouth, a pair of very dense brushes of fine hair, and these brushes are kept in constant motion, combing from the water and into the mouth the minute organisms upon which the creature subsists. At the other end of the body is a cylindrical tube of moderate length, at the tip of which are the spiracles or openings to the breathing tubes, by means of which air is secured from above the surface of the water; for the larva although strictly aquatic as to food and other habits, is yet dependent for its supply of oxygen upon the outer air, and must come to the surface at short intervals to breathe. Indeed the favorite position of this larva is to hang head down in the water, the tip of the tube at the surface, the mouth brushes hard at work securing food. This peculiarity of the insect gives us a certain advantage in our efforts to control their increase, for a film of oil on the surface of the water in which they live will prove rapidly fatal, the oil entering into the body through the spiracle when the insect attempts to get air.

In from five to seven days during the summer, the larvæ are full grown and change to pupæ in which the outline of the future mosquito can be made out hunched into a comma-shaped mass. This pupa also gets its air supply from above the surface, through two small, trumpet-shaped tubes on the thorax, so that it is also fatally affected by oil. It is active in this stage when disturbed, and moves about rapidly but erratically, by means of two paddle-like structures at the end of the abdomen. When it becomes quiet it rises automatically to the surface, and there rests until ready to assume the adult stage, which is in from one to three days in summer.

In cool or cold weather all the stages are lengthened and, whereas eight days from egg to adult is perhaps a normal period, this may be increased to two or even three weeks. The adult male is incapable of sucking blood; but the female is ready to bite twenty-four hours after she becomes developed, and in three or four days thereafter is ready to lay eggs. The life period of the male is always short, since his only function is to fertilize the female. The life of the female depends upon her ability to find a place for her eggs. When she has placed them her purpose in life is filled and she also dies. If she finds no suitable place she may live for weeks and bite several times. Those females that develop late in fall do not feed after they are fertilized, but seek some convenient hiding place in a cellar, barn or outbuilding and remain there dormant throughout the winter. They become active again in May, but larvæ are rarely found in any number until well along in June. This species occurs throughout North America and a close ally occurs in the old world.

The yellow-fever mosquito, *Stegomyia calopus*, or *fasciata* as it used to be called, is a smaller species, black in color, with white marking on the body and legs. It is rather a pretty creature, an inhabitant of the more southern states and of the tropical and subtropical regions of America generally. On the Atlantic coast it does not extend normally north of Virginia, and this marks the limit to which yellow-fever may extend under ordinary conditions. I am not unmindful of the fact that yellow-fever has occurred in New York and Philadelphia; but the conditions permitting these epidemics are now understood and cannot be again reproduced.

In habit, the *Stegomyia* is not unlike *C. pipiens*, and like it breeds in all sorts of dirty water. It is very sensitive to cold, and the first frost puts an end to its activities. It is even more domestic than its ally and seems to be confined to the vicinity of human settlements. It is as susceptible to oil, in the larval stage, as any other species and also hibernates as an adult. The eggs are not laid in rafts, however, but are placed singly, not even necessarily in water, and may remain dry for a considerable period without losing vitality. When they do become water-covered they hatch, and the life period and stages are similar to those of *pipiens*.

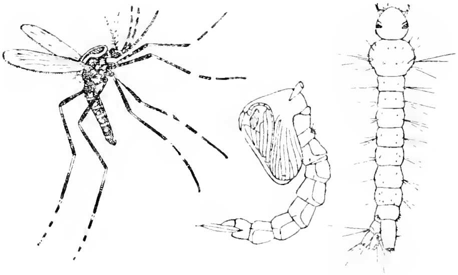

FIG. 98.—The yellow-fever mosquito, *Stegomyia calopus*; larva, pupa, adult.

The species of *Anopheles* are longer and more slender than the *Culex*, and the wings are usually more or less mottled or "dappled." The adult females hibernate in houses when they can get in, and in May or June lay eggs on the surface of water, singly or in little groups, but not in boats or rafts. They are kept afloat by a peculiar lateral supporting structure and hatch in a day or two after they are laid. The resulting larva or wriggler is altogether unlike that of *Culex* or *Stegomyia*. It is flatter, with a proportionately smaller head and a much shorter breathing tube, and lies flat on the surface of the water. It has similar mouth brushes but gets its food from organisms that float on the surface film. Its floating habit enables it to live in very shallow water, and in places where no fish except the smallest top minnows can follow.

For breeding places the species of *Anopheles* select moderately clean water, and prefer the grassy edges of large pools, ponds or swamp areas, or the eddies or dead corners of sluggish streams or ditches. They do breed in lot pools, however, and even in rain barrels, pails or tin pans. Cess-pools, sewage water or dirty gutters are not attractive to them.

Despite this difference in habit the larvæ are as much susceptible to oils as are those of *Culex*, and in the pupal stage the differences are much less pronounced. While in a general way, the species of *Anopheles* are referred to as malaria carriers, not all of them are able to serve as intermediate hosts. The most common and widely distributed form known to be dangerous is *A. maculipennis*, which has two fairly well-marked dusky spots on each wing.

None of the domestic or house mosquitoes are great travellers, and they rarely fly for any considerable distance; but there are species breeding in the salt marshes along our coasts, both Pacific and Atlantic, that migrate long distances inland, drifting with the wind twenty miles or more in a single night. These species lay their eggs in the marsh mud and winter in that condition. The larvæ, which resemble those of the house mosquito, develop equally well in salt or fresh water, and mature in about ten days from the date of hatching. In the egg stage they may remain dormant for months and perhaps for years.

There are many other kinds of mosquitoes important as nuisances, but not a menace to health, whose consideration here would carry us beyond the scope of this essay.

The one uniform requirement for development—water in which they may breed—gives us the clew to the method of control, and our efforts should be intelligently directed to eliminating such places by draining or filling rather than to destroying the larvæ after they have begun to develop.

Sometimes, where it is recognized that mosquitoes are hibernating in numbers in a house or cellar, it may become desirable to attempt their destruction during the winter. This can be accomplished by fumigation with either stramonium or culicide. Stramonium is simply the powdered leaves of "jimpson weed," which grows almost everywhere within the United States, and it is made up with one-third its weight of saltpetre to make it burn better. Eight ounces of good stramonium is sufficient for 1000 cubic feet of space and the fumes are not poisonous to man. Culicide is a combination of equal parts by weight of carbolic acid crystals and gum camphor. Dissolve the carbolic acid crystals over a moderate heat and pour over the camphor broken into small lumps; the acid dissolves the camphor and the solution is permanent when kept in a stoppered jar. It requires three ounces of this culicide for every 1000 cubic feet of space and it should be evaporated in a shallow pan over an alcohol or other lamp. This will kill flies as well as mosquitoes and is not dangerous to human life. The mixture is inflammable, however, and must be used with that fact in mind.

Whichever of these materials is used, the room to be fumigated must be made as nearly air-tight as possible, and must be kept closed at least an hour to make certain of a satisfactory effect on the insects.

Fleas are specialized flies, adapted for a particular mode of life, and their habit of more or less indiscriminate biting has laid them open to suspicion in

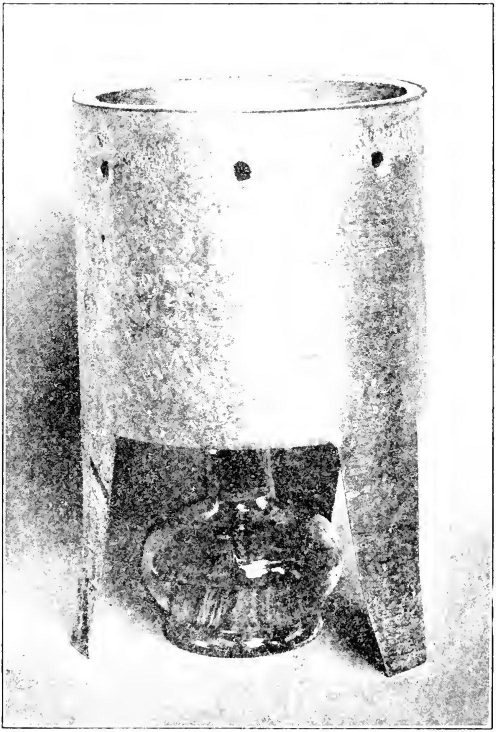

FIG. 99.—A home-made evaporating outfit for "culicide," using a section of stovepipe.

various directions. Their connection with the spread of the "plague" seems to be demonstrated and that disease is now fought in the rats from which the fleas transmit it to man.

Fleas live in their adult stage on hairy, warm-blooded animals, feeding on their blood, and their transversely flattened form set with spines all directed backward enables them to move about freely and quickly. Their eggs are dropped in the dens or nests of their hosts, and the larvæ, which are slender, white and

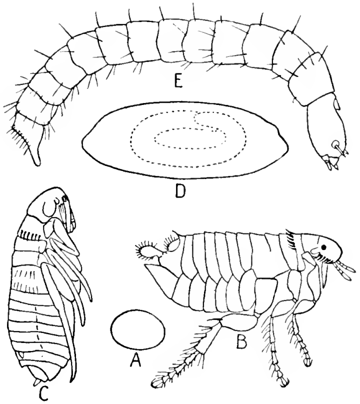


FIG 100.—The common cat and dog flea: *a*, the egg; *b*, adult; *c*, pupa; *d*, larva coiled in silken case; *e*, larva.

worm-like, live on the dead and decaying animal and vegetable matter always present in such places. In houses, the common dog and cat flea is able to develop its larvæ in the material accumulating in the crevices between floor boards and similar situations, and in the adult stage almost any kind of flea will bite any warm-blooded animal upon which it may happen to get, even if not capable of maintaining itself there. So man, though unfitted because of his hairless skin to serve as a host for fleas, may nevertheless be bitten by any of those infesting any of the animals that live with him or in his dwelling places.

In an ordinarily well-kept house flea larvæ cannot develop; but occasionally, when such a house has been kept shut up during a summer, a brood of larvæ may develop and become annoying. In such case a free use of gasoline in floor cracks and similar places where the flea larvæ live will generally give relief.

The subject as presented here is a mere outline of what is known and believed; there are other insects that undoubtedly facilitate the spread of disease in man, directly or indirectly, and there are many more that do this for other vertebrate animals. Their importance from this point of view cannot be overestimated, and at the same time it is eloquent testimony that for many ages man and these insects must have dwelt together, to permit so close a union as identity in parasitic affections argues.

# CHAPTER X

## THEIR RELATION TO THE HOUSEHOLD

SINCE man has enjoyed the shelter of a dwelling, however simple, he has had in it something in the nature of furniture and bedding, and he has usually felt the need of storing, in time of plenty, supplies that might be drawn upon in seasons of want. And stored products of all kinds have ever been attractive to those insects that feed upon dead animal or vegetable matter; not necessarily decaying or decomposing matter, but simply that which is without active life and ready to return to its original constituents, whether by way of the human alimentary canal or in any other manner. Stored seeds are not dead in the strict sense of that term; but it can stand here for that inactive condition of vegetable life in which it is not capable by any process of growth of outrunning or opposing the attacks of such creatures as attempt to feed upon it.

There is no one species of insect that is confined to human habitations. All are species that also occur under normal outdoor conditions, and that could continue even though every trace of mankind were removed from the face of the earth; but as to some of them the struggle would then be very seriously intensified.

We might arrange the species that associate with man so closely, in the order of the manner in which they affect us, and that would be the better method were we intent only on a treatise dealing with household pests; but I have preferred to follow the general scheme of dealing with the orders and giving those general habits that have induced certain of their members to frequent man's neighborhood.

I begin by stepping outside the insects altogether and dealing with the common house "centipede" or "thousand legged worm." It is a frail yet formidable looking creature with a large number of long slender legs, yellowish-gray in color and mottled with blackish. It has a pair of long, many-jointed feelers and the last pair of legs are unusually extended so that they give a weird impression of danger that makes most people hesitate about interfering, except through the agency of a broom or similar weapon. It is most commonly seen in cellars or on damp walls, but may occur almost anywhere in the house, and its mission is quite innocent; praiseworthy in fact, for it is predatory on other household insects, feeding on roaches, bed-bugs, moths and such similar creatures as it is able to get hold of. The specimens should really never be interfered with at all; but few persons like their looks and there is neither danger nor difficulty in killing them. At a touch the thing collapses into a struggling mass of legs, which continue to wiggle for some little time after they are separated from the body. The natural habitat of species of this kind is under the bark of trees, under logs

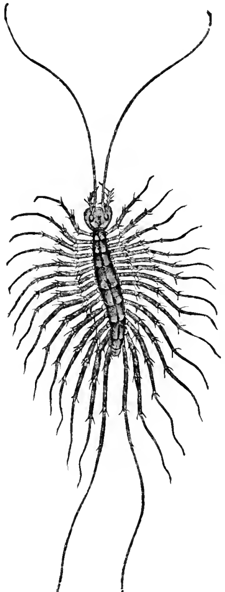

FIG. 101.—A house centipede, *Scutigera forceps*.

or in other damp, sheltered situations. There is a small poison gland connected with the mandibles which, however, are incapable of piercing the human skin. Nor is the poison sufficient in quantity and character to cause any appreciable trouble, even if by any combination of circumstances the jaws could be forced into the flesh.

Among the true insects the lowest or most primitive order, the *Thysanura*, are represented in houses by several species. In the cellar of the farm-house where vegetables and other provisions are stored in quantity, they occur wherever it is damp and wherever the least suspicion of decay occurs. There are here several species of bristle-tails and spring-tails; small wingless creatures, soft-bodied, with indefinite mouth parts, that feed only where a way is opened to them by other things; but when that way is opened their feeding promotes the decay that first gave them entrance, and by their numbers they may become troublesome. Remembering their fondness for damp places the free use of lime and thorough ventilation will serve to disperse them. Some are so lowly organized that the tracheal breathing system is not fully developed and oxygen is absorbed through the damp skin. To such creatures dryness is fatal. In cities and towns few of these insects are found, and practically only two species of "bristle-tails," or "fish-moths" or "silver-fish" occur. One of these species is quite tough in texture, somewhat convex, evenly

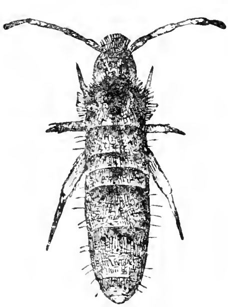

FIG. 102.—A spring-tail or Podurid.

silvery, and found only in cellars or damp places; the other is very soft-bodied, the silver mottled with blackish or gray, and found in dry warm places like

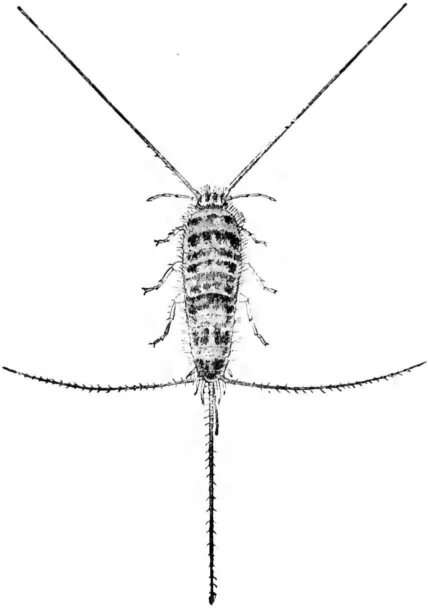

FIG. 103.—The silver-fish, *Lepisma domestica*

kitchens, bake-houses and pantries. They feed on all sorts of starchy products and nibble preferably at bits of bread, cake and the like; but at a pinch they gnaw the calendered surface of paper or book bindings, and have been known to attack the glossy surface of a shirt front. They are rarely abundant enough to be a real nuisance, and wherever it is necessary to deal with them they yield readily enough to pyrethrum or gasoline whichever may be indicated; naphthaline serves very nicely as a repellent wherever one is necessary. Ordinarily, killing the specimens as they come under observation answers every purpose.

A little higher in the scale of development come the "book lice" belonging to the family *Psocidæ*, allies of and somewhat resembling the biting lice that have been already dealt with in their relations to other animals. Indeed, as a rule housekeepers when they notice these little insects among their stores of linen or in dusty corners of drawers, suspect them of being really parasites or true lice. But all lice, whether of the biting or sucking variety, are awkward, slow-moving creatures on a level surface, while these little Psocids are active and agile, running backward or forward with equal readiness, and so spry as to be not easily captured. When captured, instead of being tough and leathery in texture, requiring an effort to crush, they are soft and go to pieces at a touch. They are never found on animals of any kind, and what they are after is the little organic particles that they get from any sort of dry animal or vegetable matter. A dead fly will be reduced to a fine powder by them in a few days when they are abundant, and in collections they are occasionally something of a nuisance; but almost any pungent odor drives them away, and besides we have always the resource of not

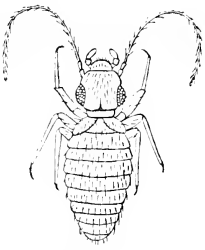

FIG. 104.—A book louse.

leaving anything about that is attractive to them. Camphor, naphthaline, oil of sassafras, carbolic acid, and oil of peppermint have all been employed with good effect and, really, almost anything answers. Occasionally they infest an old straw or corn husk mattress in great numbers, and in such case the only real remedy is the fire. Other members of this group composing the order *Corrodentia* or "gnawers," a branch of the great Neuropterous series, are winged and live outdoors, as indeed do many of the wingless species; but always their food is dried animal or vegetable matter, so that the only reason why any species occurs in our houses is that the materials that they feed upon are found there.

Scarcely higher in development so far as structure is concerned are the Termites, or "white ants;" but though low in physical organization they are most wonderfully developed on the social side, standing scarcely inferior to the true ants. Termites are not numerous in species anywhere in temperate or frigid North America, and throughout most of our country only a single species occurs or is at all common—the *Termes flavipes*. In warmer countries and in the tropics, the number of species is much greater, while in Africa they have their point of greatest development. In that country the insects themselves are house builders, their habitations rising in many cases ten feet or more above the surface in turret-like form and clustered in great villages. But it is not with their peculiar organization nor interesting social life that we have to do here; but with their habits when they leave their own dwellings and invade ours. Yet to fully understand the creatures and how they come to be with us at all, we must know a little of their history. The popular term "white ant" is derived from the pale, yellowish-white workers of the common species, which are wingless, about one-fourth of an inch long, flattened, with a large head, small thorax and a rather large, ovate, bluntly terminated abdomen or hind body. Outdoors they are usually found in small numbers under flat stones at the edges of woods, in fallen trees, old stumps or in woody material generally. When a colony is disturbed most of them will dive out of sight into galleries underground

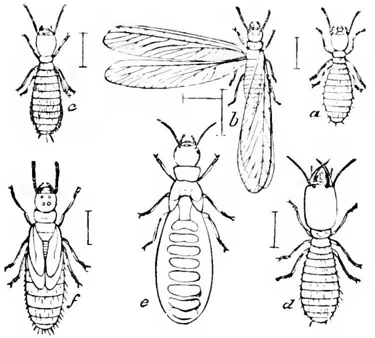


FIG. 105.—*Termes flavipes*.—*a*, larva; *b*, winged male; *c*, worker; *d*, soldier; *e*, female; *f*, pupa.

and seem to be concerned only in getting away as fast as possible. They are very soft, helpless, without eyes, and in the day-light are absolutely defenseless. A few specimens a little larger in size will appear bolder than the rest, not quite in such a hurry to get away, and when we look at these more closely, we note that the head is larger and that they have longer, pointed jaws or mandibles. They are indeed the soldiers of the colony, and developed for its defense; but very helpless soldiers at that when uncovered, because like the workers they are wingless and blind. Both workers and soldiers are represented in both sexes, but the reproductive organs are undeveloped and neither sex is capable of reproducing. If we get at the home of a large colony in an old tree, in late fall or early spring, we may find with these white, wingless forms, some decidedly larger, rusty brownish specimens, which have well developed long wings lying flat on the back and well developed eyes. These are the males and females which during the warm days of spring leave the parent nest in a body and swarm. They are sometimes seen emerging from some old fence-post or house timber in great hordes and for a short time fill the air. Their flight is very weak, the two pairs of wings being unconnected and very similar to each other, and when they have mated they disappear. The majority of all these specimens die without being able to found a colony and the method of starting varies somewhat with the species. For our present purpose it will be sufficient to say that in a developed colony there is one queen or egg-laying female, with abdomen so distended that she is helpless, simply oozing eggs which are taken and cared for by the workers. Or there may be several "complemental" females which have never left the nest and never become fully winged. In any case the colony consists of many thousands of individuals and from the centre, where the queen resides, galleries extend in all directions. The food is usually wood-fibre; but may be any sort of dry vegetable products even when made up into thread, paper or other artificial forms. Because they are blind the workers shun the light and always work in burrows or galleries, first eating out the fibres as food and then using the excrement to form cells or chambers where the raw tissue has been removed. When a nest of Termites has its centre near a wooden dwelling, the galleries may at almost any time reach some of the posts or supports:

and when they do, the insects work into and through the wood in concealment, until suddenly there is a collapse. In the tropics they get into floor boards and the furniture resting on it, always mining out of sight until there is a breakdown.

Where the insects are plentiful their habits are well known and house builders use all sorts of precautions to keep them out and never leave furniture in one place very long. In the more northern countries where *T. flavipes* only occurs, or is the only common species, usually fence- or stair-posts only or the timbers of barns and other out-buildings are attacked and then the problem is getting at and destroying the central nest, which is usually in an old stump or log not far away. Only occasionally do they get into the beams or timbers of dwellings or other inhabited buildings; but when they do, they usually work until the timber is ruined before their presence is suspected. In such cases there is nothing to do but remove the infested material and put in iron or, before putting in another wooden support, treating it with some creosote or other poisonous preparation unless the central nest can be found and destroyed. They have been known to get into a store-house and to ruin large quantities of supplies before their presence was even suspected, and into a masonry vault containing records, leaving the pile of books and records fair to all outward seeming, but a mass of cells and excrement behind it.

Yet a little further up come the members of the order *Orthoptera*, including some of its most unlovely fellows, the roaches; but also a few that have appealed more to poets and dreamers in the chimney corner—the crickets, including of course those on the hearth. Crickets are generally accidentals and their presence is usually due to their search for shelter. They are sufficiently catholic in their tastes to exist for some time on such scraps as they can find indoors and so the cheerful chirp is not infrequently heard in some country localities. But there are other species, with other habits. In sandy districts and often along the coast where crickets are very abundant outdoors, they are apt to get into houses in their general wanderings and develop an inordinate fondness for woollen goods, especially if they are at all damp. It has been my fortune to accompany a fisherman on an early spring trip to the club-house at the seashore, after it had been closed since the preceding fall, and I watched him open the drawers of a bureau containing his store of clothing, and then I listened to his expression of regard for the crickets that had found the garments so toothsome; and I grinned in no holy joy, for that same fisherman had always regarded insects as unworthy of consideration, and knowledge concerning them as of no account whatever. And lo, now he was forced to appeal to that knowledge and ask advice! It was all very easy and meant simply have everything perfectly dry when put away, and have things put into a trunk or chest rather than a drawer. Where crickets do get annoying, pieces of soft bread dusted with Paris green or white arsenic will soon rid the house of them.

As for roaches, there are a few that have been distributed by commerce throughout the civilized world and, in addition, some localities have species of their own which, while living chiefly outdoors, rather commonly get indoors as well. In the tropics roaches are most numerous, and in the warmer parts of our own country even the common species are more abundant and troublesome than they are further north.

All roaches have much the same appearance and general habits. They are flattened, soft-bodied with long spiny legs, long slender feelers, and the head bent down so that the mouth comes almost between the front legs. Some are winged and some are not; but even the winged species do not as a rule fly readily and some never at all. They hide in crevices during the day and roam abroad at night seeking what they may devour, and they are not at all particular what it is; dry scraps of animal matter, moist vegetable matter—almost anything indeed that can be eaten. Moist articles are

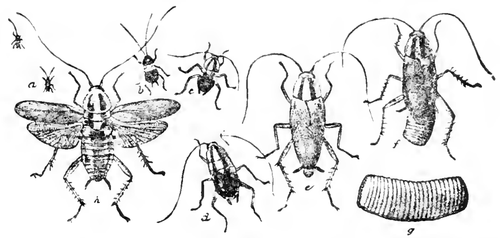


FIG. 106.—The "Croton bug," *Ectobia germanica*: *a*, first; *b*, second; *c*, third; *d*, fourth stage; *e*, adult; *f*, female with egg case; *g*, detached egg-case; *h*, adult with wings spread.

preferred and a warm wet dishrag which was not washed after using has almost irresistible attractions. If there was only one roach in a kitchen and I wanted that roach I would place just such a rag on the middle of the floor soon after dark, and I would expect that roach there before ten o'clock. This applies more particularly to the large oriental roach or "black beetle" which is very heavy, does not climb much, and prefers moist places.

The "croton bug" or "German roach" is a much smaller species, climbs readily, and favors drier places. It is much bolder than the oriental species, and is not infrequently seen during the day.

How to get rid of roaches is a question frequently asked, and judging by the number of infallible roach powders and foods on the market is one frequently and satisfactorily answered. Most of the dry powders depend on a mixture of sugar or chocolate with borax, the latter being the killing agent, the sugar or chocolate merely to attract. Mix equal parts of sweet chocolate and borax in a mortar, so as to mingle thoroughly, and spread where roaches abound, removing, so far as possible, all other food particles.

Roach pastes usually contain phosphorus or arsenic and are applied on pieces of soft bread which is a favorite food. An ingenious Australian scheme is to mix one part of plaster-of-paris with three or four parts of flour and set it on a small saucer easily accessible to the insects. Feeding on this makes the roaches very thirsty and they seek water; dishes of this should also be placed near by and when this is added to the flour and plaster, the latter sets and clogs the intestines. This is a very simple, safe and inexpensive method, and once the flour and plaster are set out, needs only attention to keeping up the supply of water. In any case when a house is once badly infested by roaches and it is desired to clean them out, it means a campaign. No one application will ever be successful, but persistence will be victorious in every instance.

There are many interesting peculiarities about roaches, but none greater than their egg-laying habits. The entire egg supply of the female develops simultaneously in a sac or case attached at the end of the body, technically known as an oötheca. As the eggs develop this case enlarges, until all have attained full size and the eggs are almost ready to hatch. Then the female drops it in some sheltered corner, the seam along one side splits, and all the young roaches come out at about the same time. As a matter of policy it is always well to begin a roach campaign *before* the egg cases have been fully developed, as there are then much fewer specimens to be dealt with.

The *Hemiptera* as an order are always difficult to place in a linear series among the mandibulata, but they contain one species that must be referred to among the forms dwelling with man—the "bed-bug," *Cimex lectularius*. It has local names in different parts of the

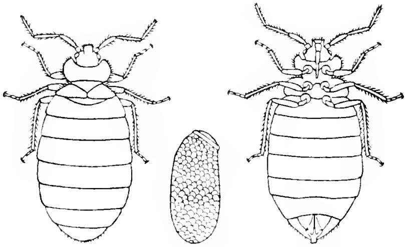

FIG. 107.—The bed-bug from above and below and egg.

country, but "bed-bugs" are always recognized even where they are commonly referred to as "chinches." There are quite a number of the *Hemiptera* that are very much flattened and fitted to live in narrow crevices; but none more than this bed-bug which occurs now-a-days only in connection with human habitations. An allied species lives in the nests of swallows, sometimes in great numbers, but does not infest houses.

The pest is found all over the world and has been recorded ever since there were any records; so there is an immense fund of information concerning it—some true, some more or less imaginary, like the tales of the ingenious measures adopted to reach sleepers in beds which had been isolated so that they nowhere touched the wall and had the posts set in pans of water. The bugs are normally red brown in color, but when first hatched or when compelled to go without food for a long period, they are almost transparent whitish. Just how long they can go without food seems to be not definitely determined, but it is certain that houses entirely uninhabited for a year have been found infested with very hungry bugs when again put to use. The insects moult five times and normally feed only once between moults, a period of five or six days. Nor, when the insects have fed, do they always or even usually stay in the bed occupied by the victim. On the contrary, especially where there is a metal bed, they are very apt to leave it and seek some other piece of furniture or get behind base-boards, picture mouldings, trimmings or even behind the backing of picture frames. In one case the resort for a considerable colony was found in the large old-fashioned lock on the room door. In the large wooden bed of the older type there was usually abundant chance to hide and these beds were difficult to get and keep clean, especially before the days of gasoline. In such cases a large percentage of the bug population might be confined to the bed; but the life of the "chinch" becomes ever more difficult under modern conditions, and with a little care, practical exemption is securable in a well-ordered household. Their occasional introduction is almost unavoidable where public conveyances are used. I have seen them in railroad cars, trolleys, boats, omnibuses and carriages, and have noted them crawling on the clothing of well-dressed fellow passengers who probably did not bring them in. It means, therefore, in the average household, a more or less continual vigilance on the part of the housekeeper, and one of the first and most characteristic signs of their presence is the round black spot produced by their excrement on the bed linen or other places where they have rested. Some extremely sensitive persons recognize their presence by the peculiar buggy odor, which is not ordinarily noticeable until the insects are handled. Eggs are laid in the crevices inhabited by the adults, in small batches, and oviposition extends over a considerable period. They are whitish, oval, reticulated, and, like most hemipterous eggs, of rather large size, so that they are easily seen and recognized. The total life cycle, from egg to adult, is about forty-five days, and the insects do not breed during the winter, except under unusual conditions.

Given an ordinary infestation in an ordinary bedroom, thorough work would mean taking out all bedding and taking apart and examining the bed. With a large bulb pipette force gasoline into every crevice however small, and drench the binding and tuftings of the mattress, wherever there is a folding over that might serve as a hiding place. Force gasoline through the pipette behind and under the base-boards, under the picture moulding, behind all the trim of the room, and into all other possible hiding places. Treat the wash-stand, bureau and all other furniture to liberal doses, and carefully examine all pictures for signs of either eggs or "spots." If necessary remove the back to see whether the insects have made their way under it. The gasoline will kill every insect it touches; but not the eggs, so that a second treatment must be made to reach the insects that hatched after the first. It will require about one gallon of gasoline for a bedroom of good size, with a normal amount of furniture, and the material will hurt neither fabrics nor paper. Bad infestations in hotels, boarding-houses or tenements are best reached by fumigation with hydrocyanic acid gas, which will be described later on.

In the southern and southwestern states there is another, much larger species that has also developed the house habit and is known as the "big bed-bug," or the "blood sucking cone-nose," *Conorrhinus sanguisugis*. It belongs to the family *Reduviidæ* or "assassin bugs," all of which are predatory in habit, and its bite is a serious matter, causing much swelling and often inflammatory and febrile symptoms. These insects are so large and so little fitted for hiding that ordinary care in looking after beds and rooms will detect them and prevent trouble.

Among the *Coleoptera* or beetles there are a large number that live with us and cause trouble. All, however, are species quite capable of taking care of themselves outdoors and come to us only because we have in our possession or in the building some of the products upon which they normally feed.

A good illustration is found in the species belonging to the family *Dermestidæ*, nearly all of which are feeders upon dried animal products. The term "dried animal products" is a broad one and includes little scraps of meat left on an old bone, a bit of hide remaining where an animal has decayed, or a pile of hair or wool, no matter where found. A dead insect found in the field serves as a nidus in which an egg is deposited, and if the dead insect is in our collections that is not a matter of concern to the beetle, provided it can be gotten at. We have, therefore, larder beetles, leather beetles, museum beetles, carpet beetles, and a variety of others of the same type, all seeking in our dwellings that dried animal food which they require, and whose presence is indicated to them by the discriminating sense of smell with which they are fitted.

All the members of this family are dull brown or blackish, clothed with gray, white or colored scales arranged in more or less distinctive patterns. They are more or less oval, without conspicuous head, and with short legs and feelers that can be retracted and folded close to the body, so that the insect, playing 'possum, looks like a bit of dirt or other fragment among the mass in which it lives. The larvæ or grubs that do the real damage are stumpy, worm-like creatures set with brown hair, often with a longer brush at the end of the body, sometimes with a series of tufts at the sides.

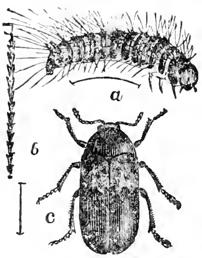

FIG. 108.—*c*, the larder beetle; *a*, its larva; b, larval hair.

The carpet beetles are best known and least liked of all these species, and in the adult stage when they frequent the flowers in our gardens, are rarely recognized. The so-called "buffalo-moth," in the adult stage, is really very pretty, with its lines of brilliant red and white scales. This insect is a feeder on animal hair, and that accounts for its attacks on woollen goods and feathers. Its close ally, the black carpet beetle, has similar habits, and both sometimes get into a feather pillow and create havoc. Where the cover to the pillow is of the right texture, the feather fragments are occasionally worked into it so as to form a soft, felt-like covering, that puzzles the enraged housekeeper when she discovers the condition of her feather stuffing. All woollen and feather fabrics are attacked and fed upon, and the best way to prevent trouble is to keep those things not in actual use shut up until midsummer. After that there is no further danger from these species. Of course the usual repellents, camphor, naphthaline and the like are useful, and gasoline is an excellent destructive agent; but after all, care and protection by tight boxes or paper bags is best. When carpets on the floor are attacked and it is not convenient to take these up, a liberal use of gasoline is indicated, until no further traces of the insect work are noted.

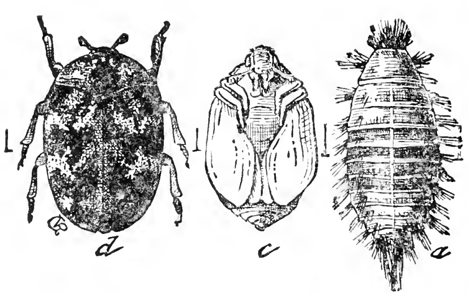


FIG. 109.—*d*, the carpet beetle; *a*, its larva, the "buffalo moth"; *c*, pupa.

Almost every museum and every collector of specimens of organic natural history has to do with two or three species that attack such dry products by preference, and here again the ordinary repellents are brought into use, supplemented by a free use of bisulphide of carbon, ether or chloroform. None of these is advisable in ordinary household use because of either expense or danger, so there is no necessity for going into details. The larger species such as the larder beetles are usually controlled by screening or keeping the provisions properly covered. The leather beetles that occur more commonly in manufacturing establishments must be dealt with according to the conditions as they exist in each individual case.

Quite a different series of species attack our stored grains and other vegetable products. The largest and most conspicuous of these are the meal worms—long, yellowish, slender worm-like grubs with a brown head

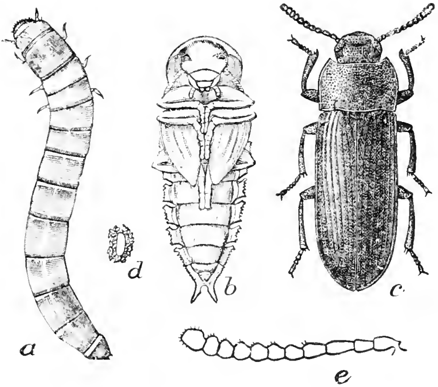


FIG. 110.—*a*, the meal worm; *b*, pupa; *c*, adult beetle, *Tenebrio molitor*, *d*, its egg; *e*, antenna.

and anal segment, reaching the length of an inch or more. These live in meal of all kinds and are more common in the barn and stable than in the house though not unknown there by any means. The parents are oblong flattened black beetles nearly three-quarters of an inch in length, and are usually found in the same places as the larvæ. Incidentally these meal worms are great favorites with our feathered friends, and they are raised in great quantities as food for cage birds of various descriptions.

Allied in appearance but very much smaller, come the various species of flour and grain beetles; the larvæ, very slender whitish grubs, not much over an eighth of an inch in length, the adults equally slender, flattened brown beetles, less than that length, or scarcely attaining it. They accumulate wherever meal or grain products of any kind are kept open and allowed to stand for any length of time. In pantries or closets where jars or

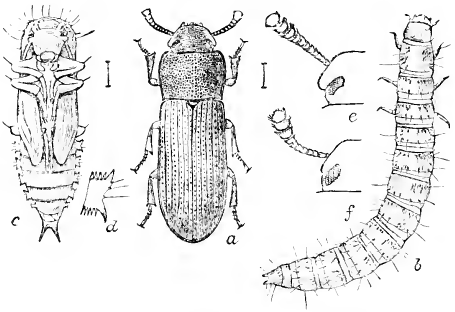


FIG. 111.—The confused flour beetle, *Tribolium confusum*: *a*, adult; *b*, larva; *c*, pupa.

receptacles are never entirely cleaned out before replenishing, they find their best opportunity for multiplying, and the best method of checking them lies, in consequence, in cleaning out thoroughly every receptacle for such products before putting in a new supply.

In peas, beans, lentils and the like, "weevils" often make their appearance, and that is manifested when in such seeds one or more round holes about one-sixteenth of an inch in diameter may be noted. Now while, ordinarily, these insects breed outdoors, and simply pass the winter in the seeds that were attacked in the field; yet in the artificial warmth of our houses the beetles emerge in late fall or during the winter, and lay their eggs on the dried peas, etc., so that what may be a pretty fair lot of legumes in fall, may be an utterly useless lot of vegetable débris, in the spring following. The grubs in this case are chunky, white creatures, curled up inside the seeds, and the beetles are small, very chunky gray forms, with very stout hind legs and the hind part of the abdomen very abruptly terminated. The ordi-

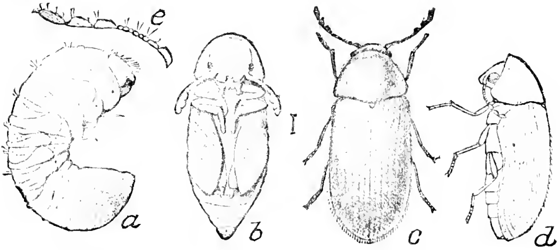


FIG. 112.—The drug beetle, *Sitodrepa panicea*: *a*, larva; *b*, pupa; *c*, *d*, adult.

nary householder sees little of them because, as a rule, only a small stock of such products for almost immediate use is at hand; but to the farmer, the seedsman, the grocer or other dealer, the matter is sometimes serious. Fortunately we can reach the insects even inside the seeds by the fumes of bisulphide of carbon, in a manner to be pointed out a little later.

Then come those species that get into more solid vegetable fibre, like roots, stems or even wood, and many of these belong to the little family *Ptinidæ* which contains a mixture of odd and bizarre forms, very different and yet very similar in general character and habits. The drug beetles, *Sitodrepa panicea*, and the cigarette beetles, *Lasioderma serricorne*, are examples of such forms and, in the adult stage, are little, brown, more or less cylindrical species, not much if any over one-tenth of an inch in length. The eggs are laid in or on almost any kind of wood or leaf tissue, and the larvæ which are very small, curved, white grubs, bore into this tissue reducing it to powder. Cigarettes, cigars and plug tobacco are often attacked and little round holes through the surface tell the tale of the destroyer. So the roots of licorice and hellebore are equally favorites, and may be reduced to powder, while occasionally willow- and rattan-ware is seriously injured.

The somewhat larger species of *Hadrobregmus*, and the species of *Lyctus* or powder post beetles belonging to the same family, occur in the woodwork of houses or in furniture, and may create serious trouble. They live and bore in the seasoned wood, mining it in every direction and in time reducing it to a mass of powder. Little round holes, from which sometimes little masses of sawdust are ejected, declare the character of the insects at work here, and for them there is no one method of treatment. Creosote, gasoline, tar, paint and similar penetrating or covering mixtures are applied with more or less good effect, and which of them is to be used depends upon the especial conditions of the attack.

In the order *Lepidoptera*, the "clothes moths" have become adapted to a life in our dwellings and are rarely found elsewhere. They belong to the great group of *Tineid* moths in which the early or primitive characters of the order are yet well marked, and as a relic of their ancestral habits they retain the practice of making cases or shelters in the larval stage. This serves as a protection to the caterpillar and as a means of concealment;

for being made of the material among which the insect feeds, it is not usually conspicuous. The divergence from the usual vegetable feeding habit of caterpillars is a specialization that is quite marked, because it is not only a feeding upon animal tissue but upon dried or dead animal tissue. In Chapter VII it was pointed out that some moths lived in the heavy fur of certain animals so that they became literally moth-eaten during their lifetime, and this habit of feeding upon such

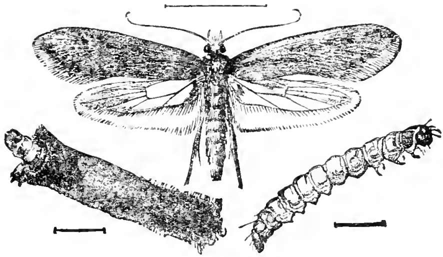

Fig. 113.—A clothes moth, *Tinea pellionella*, with its caterpillar in and out of case.

material when removed from the animal is only a little further specialization in the same direction. It furnishes, also, an explanation of why woollens and materials made of animal hair or fibre, in whole or in part, are subject to moth attacks, while linens and cottons are practically exempt.

The "moth" itself, or "miller," is a small, glistening, light yellow creature, with very slender, long fringed wings, and it may be seen fluttering about in the dusk of early evening in our rooms during late spring or early summer. If when a closet door is opened at this period a number of these moths flutter out, there is a probability of damage already caused, and very great danger of more damage to come. Not that this moth itself has done or is capable of doing any injury. Its mouth parts are such that it is practically incapable of feeding at all, and altogether incapable of feeding on solid tissue of any kind. But it lays its little whitish eggs in the woollen or similar tissue wherever it finds a chance to do so, and from these eggs hatch the little caterpillars whose mouth parts are formed of sharp jaws, quite fitted for cutting the animal fibres among which they live. Almost the first work of the caterpillar after hatching from the egg is to form a little case from the tissue among which it finds itself, held together with silken threads of its own production; and this case is enlarged from time to time as the insect grows. It is curious how these individuals differ in habit. Sometimes the cases will be made up of fibres of all colors, indifferently put together without pattern or system. At other times, and that is rather the rule, the color first selected will be adhered to, so that in a carpet one pattern may be completely eaten out, while others, of a different color, will be untouched. In my own experience I have observed a very decided preference for reds where such were obtainable, and in rag and brussels carpets I have seen the red stripes and flowers eaten, while the blue stripes and green leaves were untouched.

The period of development depends on the temperature. In the more northern United States there is only a single brood; in the middle and southern states there are two and in the extreme south and on the Pacific coast there may be more. But the insect is sensitive to cold and does not grow or develop unless the temperature is above 60°, even though it is not killed by a much lower degree. Hence has come the practice of placing furs and other valuable articles of apparel or drapery in cold storage where, even if already infested, no development can take place. The entomologists of the U. S. Department of Agriculture have determined that a temperature of 40° is low enough to prevent any development, and my own experience in the household is that until a daily average of 60° is reached, little danger is to be apprehended; but this, of course, does not mean that in closets so placed that a higher average temperature is maintained, breeding would not go on even though the outside temperature was not above 60°.

To prevent infestation, nothing is better than to brush all the clothing to be protected and then pack it into tight boxes. They need not be heavy nor large boxes, but they must be tight. Pasteboard boxes will answer every purpose if the covers are fastened at the point of junction with gummed strips and such boxes are now obtainable of almost any size, for garments of all kinds. Heavy paper bags answer the same purpose, and these are now sold for that purpose in the larger cities. They can be easily made where they cannot be bought. Even carefully wrapping in newspaper, using plenty of paper and covering joints, will answer, where the garments are packed away in trunks or moderately tight drawers. But there should be no doubt about the freedom of the garments thus put away from "moths" or their eggs. When a fabric is once infested and the insects cannot be reached by beating or brushing, a drenching with gasoline is effective, and when a closet becomes infested, it should be thoroughly sprayed with gasoline so that every crevice is reached and penetrated. Fumigation with sulphur will kill them if properly made, but there must be no metal and no fabrics in the closet when it is done. Formaldehyde vapor is ineffective.

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As for the various repellents like camphor, naphthaline, tar, etc., these are all of some value and in proportion to the tightness of the drawer, trunk or other receptacle in which they are used; but none are implicitly to be relied upon if the fabric is already infested, or if the container is not reasonably tight. Gasoline will kill every caterpillar that it touches and is the best material to use where rugs, carpets, hangings or draperies that cannot for any reason be removed are to be dealt with.

We have further, among the *Lepidoptera*, and in this same group of Tineids, other moths and their larvæ that feed on our stored products, but hardly in our houses, and such are the Indian meal moth, *Plodia interpunctella*, the Angoumois grain moth, *Gelechia cererella*, the meal snout moth, *Pyralis farinalis*, and the like. They scarcely come under this head for detailed consideration; but should be mentioned to call attention to the fact that they may be found among products often stored yet hardly to be considered as inhabitants of the household itself.

In the order *Hymenoptera* the ants are not infrequent invaders of our domestic economy. Sometimes they come in merely on exploring expeditions from outside, with no thought of remaining. It is merely part of the hunt for food, and if something is found, a squad is soon at hand to clean it out. Among such visitors comes the large black carpenter ant, which nests in partly decayed logs, branches of trees and the like, and forages for a considerable distance round about. A house near a large nest is likely to be so frequently visited as to make them a nuisance, and to abate this the colony should be located and their home destroyed. This general recommendation applies to any species which comes in as a visitor in this same way.

Sometimes ants make their nests just outside of our houses, on the lawns, and while this does not bring them strictly under this chapter head, we may digress for a moment to consider them as a nuisance. With a cane or other stick poke a few holes to the depth of about ten inches near and about the centre of the nest, and into each hole pour about one ounce of bisulphide of carbon, covering the hole by stepping on it. The fumes will penetrate throughout the galleries and kill all the ants and their larvæ that are reached. Usually one application is enough; if by any chance there is renewed activity about the nest a few days later, repeat the application.

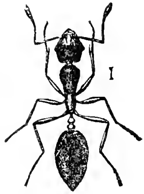


Fig. 114.—A house ant, *Monomorium pharaonis*.

Within our houses three or four much smaller species make their homes, and establish colonies. There is a small red ant, a larger black ant, a very small black ant and, more occasionally, a very small red ant. They differ materially in their habits and somewhat in their life cycle, but for our purpose are enough alike to be considered together. Like all ants the colonies consist of a queen, a large number of workers and, in the late summer and early spring, also the males and females that will at the proper time leave the nest to swarm. Only the workers are seen as a rule, and these swarm over everything in the nature of food, and cart it off to their nests which are situated behind base-boards, in crevices behind the plaster or in the masonry, or anywhere in the shell of the house where they can establish themselves. Once a house is thoroughly infested the task of getting rid of them becomes a serious one and can be accomplished only by persistent work; but it can be accomplished. In the first place locate the nests if possible and destroy by injecting gasoline or bisulphide of carbon with a syringe. Both of these are highly inflammable and should only be used where there is no fire nor open artificial light of any kind. Many colonies may be reached in this way and greatly weakened or destroyed. Others will be so situated that they cannot be reached, and the insects will simply seek less exposed openings into the rooms. The systematic campaign then consists of keeping all food products under cover so far as possible, or protected by belts of creosote or oil of lemon, which the insects will not readily cross. Set out, easily accessible in their ordinary lines of march, all the raw bones with small particles of adherent meat that come from the kitchen, and when these become covered with ants throw into the fire and burn. Or with a knife scrape the surface of a piece of meat and spread the scrapings thinly on a piece of paper. Burn this when covered, in the same way, always taking care to let none escape. Keep this up consistently and persistently, and no matter how numerous the ants may seem to be, they will become so greatly reduced in numbers that the nests are disorganized for lack of workers. There will be no one to feed or care for the young and the colonies will perish. Instead of the meat and bone method the sugar-sponge method may be employed. This means two moderate sized sponges, saturated with sugar water and pressed nearly dry. Place one near the run until the ants swarm in all its cells; then remove and drop into boiling water, substituting the second sponge in its place. The boiling kills the ants, of course, and the sponge should then be thoroughly washed to get rid of the dead insects, again dipped into the sugar water and prepared to replace the second sponge when that is ready to be boiled. It is sometimes a matter of weeks and it may be necessary to change the location or even the character of the traps several times; but, faithfully carried out, I have never known this plan to fail, and I have personally employed it in two houses occupied by me, when the insects threatened my collection and ate the fresh specimens on the setting boards when not protected by carbolic acid belts. This plan is of no avail against those ants that come in merely as foragers from the outside, like the black carpenter ants already referred to.

Of recent years a species of ant has been introduced into one of the southern states from Argentina that is far more troublesome than any of our American species. It bids fair to spread and to become a first class pest so far as it extends; indeed it has been already reported from California and may be more wide-spread than we now believe. It is known as *Iridomyrmex humilis*, and is as ready to establish its colonies indoors as out. It is under investigation by the entomologists in that section of the country and we may hope that before it gets much further, efficient methods for its control will have been developed.

In the order *Diptera* there are no species that are to be considered as guests except the common house-fly, and that is dealt with in the previous chapter in its relation as a carrier of disease. So the flea, which gets into houses not infrequently, does so as a parasite of the dog or cat, and not because of any love for man himself. Other flies there are in the house not infrequently, but in most cases as scavengers, when attracted by decaying or fermenting material, hence not strictly to be dealt with here. To be sure we have "skippers" occasionally, in cheese, especially of the odorous sorts, and sometimes in bacon and other fat; but they come very decently under the classification of scavengers and need not be further considered here.

And now, it sometimes happens that a house or a room long neglected gets into such a condition as to be almost uninhabitable by reason of insect pests of all kinds—from scavengers to parasites—and the question arises whether there is any method by which all these things can be reached at one fell swoop, or at least by two swoops; the second being made necessary by the fact that there are always some forms in the egg state and not to be reached even by fumigation with hydrocyanic acid gas, which is usually recommended under such conditions.

Hydrocyanic gas is formed by the action of dilute sulphuric acid upon cyanide of potassium, and is one of the most penetrating of poisonous vapors, fatal alike to man and insects and even to plant life when long enough exposed to it; but harmless to fabrics and not injurious to metals. The formula for each 100 cubic feet of space to be treated, is

| | |
|---|---|
| Cyanide of potassium, 98° pure, by weight.. | 1 ounce |
| Sulphuric acid, sp. gr. 1.83, by measure...... | 2 ounces |
| Water.................................... | 4 ounces |

Break the cyanide into small lumps and put the necessary amount in a thin paper bag. Put the water into a glazed earthenware vessel—a wash basin, slop jar or other bowl will answer—then add the acid slowly. The water will heat as the acid is added and will fume or bubble. When all the acid is added, drop in the bag containing the cyanide and *get out.* The formation of the gas will be retarded for a few moments while the acid gets through the paper and this will give opportunity to close the door and seal it as tightly as possible. The order of doing this is important, for if it were attempted to pour water into the acid, the first drops would cause a boiling so violent as to spatter the entire volume in every direction. It is also well to have the vessel large enough to hold at least twice the amount of liquid required, and if more than one pound of cyanide is necessary, it is better to have two or more jars.

Where only a single room is to be treated make it as tight as possible by sealing windows and other exits, but open all closets, furniture drawers and trunks so as to give free entrance to the gas. When the exit door is closed, place a damp towel or other cloth at the bottom, plug the key-hole with cotton and leave the room tightly closed for at least two hours. Then open a window or transom from the outside into the open air or into a well-ventilated hall, and allow the gas to escape for at least ten minutes before entering the room. Open all windows for at least an hour before attempting to re-occupy the chamber.

When an entire house is to be treated, first of all close and seal all windows and openings to the outer air as tightly as possible, except those through which the operators expect to leave, and those should be on the ground floor. Put into every room and into every hall the basins or jars containing the necessary amount of water; place alongside in a bottle or tumbler the necessary amount of acid and in a bag the cyanide. Begin at the top of the house, because the gas is light and rises; first pour the acid into all the jars, then add the cyanide and repeat on the floors below until the entire building is treated. Two men can work better than one in a building of any size, and in such cases the number of fumigating vessels should not be multiplied more than absolutely necessary. If everything has been properly prepared it is a matter of only a few minutes to start fumigation in a building of considerable size, and such a building should then be kept tightly closed for twenty-four hours if possible. At the end of that time no living creature not in the egg state will remain, and the house can be opened to admit fresh air and permit the escape of gas. If windows can be opened from the outside or a through draft can be obtained, a few minutes will answer, and if a scuttle can be opened from the roof, the entire house will be safe in half an hour if all the doors in the halls are open.

The directions for use here are much more formidable than the actual work; but the danger to life is so great if proper care is not exercised, that undue precautions are recommended rather than general directions that might promote carelessness.

# CHAPTER XI

## THEIR RELATION TO THE FARMER AND FRUIT-GROWER

It was emphasized in another connection that insect species that are naturally abundant are so because they have made good their position and relative number as against all their checks, and so long as natural conditions prevail they will maintain that abundance with such slight seasonal variations as may be caused by temporary favorable or unfavorable conditions.

When civilized man enters the field, serious changes in environment are produced and these changes are produced faster than the insect and other life can adapt itself to them. In a decade a wilderness is transformed to a farm or an orchard, and the balance which it has required centuries to establish is rudely upset. Those species so nicely adjusted to their surroundings as to barely maintain themselves under normal conditions may be completely crowded out by the destruction of some one factor that permitted survival, and, on the other hand, conditions may be changed to favor such a species, so as to permit it to increase out of all proportion to its past history.

The Colorado or 10-lined potato beetle, universally known as the "potato bug," *Doryphora 10-lineata*, was not always the pest that it is at present. When first discovered in the foot-hills of the Rocky Mountains it was accounted rather a rare species, that barely maintained itself on the scattered indigenous solanaceous plants. But when civilization brought in the cultivated potato, the species that had been so rare that it had practically no specific natural enemies, found conditions so materially changed in its favor that it increased by leaps and bounds, followed the trail of its food plants to the east, and in a few years over-ran the entire area of potato cultivation.

It was first described in 1824; it had become abundant enough to demand the attention of the economic


FIG. 115.—Colorado potato beetle: *a*, egg; *b*, larvæ; *c*, pupa; *d*, adult beetles.

entomologist in 1869, when Riley wrote concerning it and the methods to be adopted for its control. I still remember the joy that possessed me when, for the first time, in 1874, I found on Long Island a patch of potatoes with the insects present in all stages. They had arrived earlier, but I had not been fortunate enough to get within their range previously. As nature works, all this is so very recent that nothing has yet developed in the way of an effective natural check. It is rarely, however, that an insect is so marvellously favored by the changed conditions produced by man. Usually it is a more local species already abundant and vigorous, that derives a moderate advantage through the removal of certain of its natural checks and the greater facilities for getting food.

We must remember that an injurious insect, as generally understood, is not necessarily one that seriously injures plants, but one that causes notable harm to any plant or part of a plant that man wants for his own use. The farmer looks with equanimity upon weedy plants devoured by slugs or caterpillars, but raises an outcry when his cabbages are much less seriously eaten. Yet any insect feeding on a cruciferous weed is likely at any time to take to cabbage, and so the innoxious species of to-day may become the scourge of to-morrow.

Among the factors that are changed by the farmer in favor of the insect, none is of greater importance than the elimination of the necessity for seeking a food supply. In nature, plants and shrubs of one kind do not often grow in large numbers or on large areas crowded together by themselves. Insects are therefore compelled to seek their food and the difficulty of finding it makes a very important check. The farmer removes that when he plants orchards and fields many acres in extent and puts on the same or similar crops year after year. Clean culture, important as it is in some directions, destroys the shelter of ground beetles, of snakes, toads, lizards, tortoises and similar creatures that feed on species that go underground to pupate, like the plum curculio, or hide just below the surface during the day, like the cut-worms. The war on small rodents is especially favorable to insects, because shrews and mice are great devourers of such things. Cultivated areas are not sought by birds if they can find other quarters, and some species will simply not go into such places at all, even if they are never disturbed.

Hiding places for parasites are also limited and that is a matter of great moment, for some species seem to be dormant or in hiding for very long periods. Altogether, it may be said that in all that he does on the farm and in the orchard, the farmer and fruit-grower favors those species that feed upon his cultivated crops, and turns the natural scale against their enemies. That he does not suffer more, is merely an indication that these bird and animal friends that he eliminates, and even the predatory beetles, are not the most important checks of the injurious forms.

Another way in which man interferes with the orderly course of nature is in the introduction of plants from other countries, well adapted to live in the new locality but unable to resist the insects native to that place, and so giving them an undue advantage. But this is not a circumstance to the mischief done when an adaptable insect is introduced into a new country where it is unknown to the parasites and predatory forms native to that country! The wine-growing districts of Europe imported from America some of our vigorous American stocks and with them the *Phyllŏxera* as well. Now the *Phylloxera* in its native home is not a serious pest and there was no reason to believe that it would or could ever become such. But the European vines proved absolutely non-resistant and succumbed to injuries where the American vines would have shown no sign. The attempt to control this insect in Europe has cost millions of dollars and it is still an annual charge of many thousands on the various governments and growers. The difference between the American and European stocks is merely a matter of adaptation, our native varieties having become used to the insect when present in normal abundance. There is no specific native enemy to the *Phylloxera* and conditions in European countries are not unduly favorable to its rapid multiplication. Their vines are simply not used to the attack and sink under it.

So on the other hand, we have a long list of insects in North America introduced from foreign lands. The Hessian fly, the cabbage butterfly, the asparagus beetles, the elm-leaf beetle, the cottony cushion scale, the black scale and the San José scale, are only a few of the well-known pests that have been with us for some time.

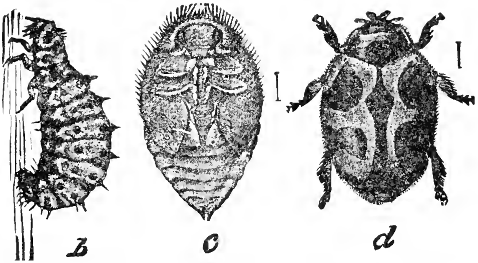


FIG. 116.—*Vedalia cardinalis*, the destroyer of the cottony cushion scale: *b*, larva; *c*, pupa; *d* adult.

Most of our troublesome forms have come to us across the Atlantic: the cottony cushion, black and San José scales came to us across the Pacific. The former never got away from the western coast; the latter has covered the entire country and has become the most generally troublesome pest of the horticultural industry. The cottony cushion scale was eliminated by a brilliantly successful experiment, resulting in the introduction of the specific check to the species from its native home. It was an experiment that we can duplicate at any time with the same factors. It is quite a different matter to import parasites and predatory forms hap-hazard to control or affect insects with which the imported species is not familiar in its native home. Here we are not making use of an adaptation, but are rather attempting to create one. Such experiments may be crowned with success, but it will be a success which cannot be predicted and it will depend on factors not apprehended by the experimenter.

While we have, undoubtedly, introduced into our country numerous first class pests—the brown-tail and gypsy moths among the latest—it is equally true that dozens of species have been introduced on imported stock or in other ways, that have never secured a foothold; and we have a few species that have started out as if to sweep all things before them and have gradually died out so as to become almost extinct. Two such species have been enemies to pear trees—the pear midge and the sinuate pear borer; the latter of which never got much beyond New Jersey, after destroying nearly all the pear trees in one district. One species, the "horn-fly," created enormous alarm among owners of cattle for a few years, swept over a large part of the United States and Canada in less than a dozen years, and is now so rare where it first appeared that specimens are at a premium for collectors. In none of these cases are specific natural enemies to be credited with the disappearance of the species. Conditions simply were not suitable in all respects, and the insects failed to adapt themselves with sufficient completeness to survive in the long run.

The important point is that those species that do survive the introduction are exceptional in vitality and adaptability, and are therefore naturally abundant and able to maintain a lead over all their enemies. If the specific parasite or other check of such a form does not exist in the new country, and is not introduced with it, a destructive increase under cultural conditions is almost inevitable.

Now in what ways do insects injure the crops and cause injury to the agriculturist? This might be answered by a reference to Chapter III, but it may be useful to take up some features more in detail, with the injury rather than the insects as the prime objects of consideration.

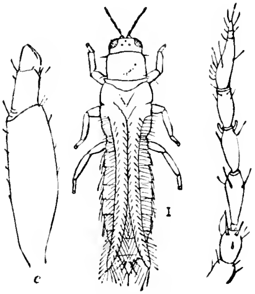

Fig. 117.—Thrips, with antenna and tarsus.

Plant lice do their mischief in part by directly exhausting the plant of sap, partly by causing distortions of growth, and partly by preventing the proper maturing of the fruit, be it on shrub, tree or vine. If on the roots, the plants are weakened or often killed and even trees are sometimes seriously injured. A secondary cause of injury is due to the production of honey-dew by the lice. This serves as a culture medium for a black soot fungus which often disfigures tree fruit to such an extent as to make it unsalable. Some of the scales have a similar habit and so do some Psyllids and Membracids. The enormous reproductive powers of plant lice render them especially dangerous, and very often the farmer does not even see the nucleus from which come the hordes that he finds on his wheat, his cabbages or his melons, a few days later.

During a spell of dry weather it may be noticed that the oats or the grass is showing white spots or becoming silver-tipped; or the onions begin to show yellow spots, turning white later, and often killing the tops. This the experienced grower will recognize as the work of *Thrips*, which scrape the surface so as to break the leaf-cells and exhaust the sap, leaving a dead spot. When these dead spots become sufficiently numerous, the leaf fails to fulfil its function and dies, or is only a burden to the plant.

Leaf- and tree-hoppers do similar work and a common example is found in the vineyard, where leaves often turn brown in summer before the fruit is ripe, because of the injuries done by the grape leaf-hopper.

Scales, soft and armored, attack trees of all kinds, in the orchards, in the forests and on the city streets. Sometimes they are so small and inconspicuous that it requires close scrutiny to find an isolated individual; sometimes they are large and showy, flaunting their numbers and threats as far as the tree itself is clearly visible. The honey-dew and soot fungus produced by the soft scales have been already referred to. Many of the armored scales produce a specific effect on the tree, besides exhausting its juices. In some cases distinct pits or depressions are formed on the surface of the bark; in others the bast is discolored and poisoned where the puncture is made, and when the punctures are sufficiently numerous the bast simply fails to do its work. Peach trees infested by the San José scale sometimes reach such a condition in fall that, after growth is completed, the bast has lost all vitality. During the winter the poison does its work; in spring the tree starts from the supply stored in the buds, blossoms and even begins to leaf out, but when demand is then made upon the roots for fresh nourishment the bast fails and the tree dies.

This poisoning effect is not peculiar to scales, but is a feature in many other of the *Hemiptera*. Some of the plant bugs of the Capsid series have it very strongly developed and Coreids like the common squash bugs are well known for the poisonous effects of their punctures on vines and other plants.

Some plant lice form galls, sores or cankers on branches, trunk or even the roots, like the woolly louse of the apple; and some of these canker sores offer excellent points of entrance for germs of disease and decay. Indeed it has been charged against some of the species that certain plant diseases are either carried or

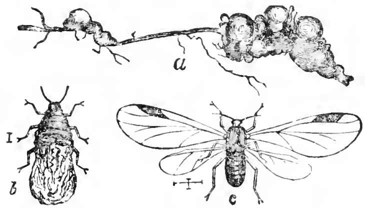


FIG. 118.—Woolly apple-louse at *c*, showing galls made on roots at *a*, the woolly wingless form at *b*.

given points of entrance by them. The root-feeding forms are particularly dangerous, because until the tree or other plant begins to show bad condition there is no way of recognizing their presence.

Not all the injury done by these various forms of sucking bugs is obvious, and so used does the farmer become to the loss that very often he does not appreciate it. A simple experiment made by one of our economic entomologists proved that leaf-hoppers in grass fields in his state were so numerous that they shortened the crop one-half. Demonstration of this was made by dividing a meadow into two equal parts, pasturing cattle on both, but collecting the leaf-hoppers by means of hopper-dozers on one part only. This part supported exactly twice the number of cattle during the season that could be maintained where the hoppers were left undisturbed.

It is comparatively easy for the farmer to estimate his loss when the green-fly drains his wheat so that instead of the expected twenty bushels he harvests only ten or none at all. The drain upon all sorts of crops by the myriad of specimens constantly sucking plant juices and reducing the yield to a less obvious extent, is rarely capable of estimation, but varies from ten to fifty per cent. almost every year on most of our staple crops. This sounds like an exaggeration, but every person who has ever studied the problem at all carefully will agree in the estimate, I think.

And then come the host of species that feed directly upon leaf tissue. They come from many orders: grasshoppers, locusts, crickets and their allies of many kinds; slugs and grubs as well as adult beetles in great variety; caterpillars of the most diverse appearance but always great devourers; saw-fly larvæ from the *Hymenoptera* and a few maggots from the *Diptera* or fly tribe. Perhaps no kinds of insects do more obvious injury than those that feed openly on the foliage and yet the real harm that they cause is not always in proportion to their feeding, because many plants and trees will support the destruction of a great percentage of leafage without material impairment of crops. This does not apply where the crop consists of the leaves themselves as in cabbage, spinach and other vegetables, all of which have their own particular insect friends.

Unfortunately some of these foliage feeders modify their habits somewhat, on occasion, and attack more important parts of the plant, *e.g.*, when the rose-chafer eats by preference the flowers of the grape and thus at once destroys the crop without injuring the plant itself. Some cut-worms, hiding out of sight during the day, cut off the stalk at base for convenience of feeding, leaving the tops on the surface to dry and perish. Or they climb on the shrub or tree and eat out the buds or growing tips, destroying the crop if not the plant.

This brings up the fact that in his method of cultivation the farmer frequently forces upon himself an injury which the insects would not under normal conditions inflict. If a field be left fallow or in grass for a year or two, it will almost inevitably attract the night-flying or owlet moths of the family *Noctuidæ*, whose larvæ, the cut-worms, feed normally on grasses and a great variety of low plants. These cut-worms, or many of them, winter half grown in sod or rubbish on the surface of the ground, coming out to resume their feeding in spring. If now, in early spring, the farmer plows this infested sod and plants corn or potatoes, or sets out cabbages, tomatoes or sweet potatoes, he deprives the cut-worms of their natural food and practically forces them to take what he has set in its place. Furthermore, while a population of one cut-worm per square foot would not be a very serious infestation in grass land, it would be destructive in a cornfield, or in a cabbage patch. And not only are cut-worms favored in this way: there are weevils known as bill-bugs, attacking corn planted on timothy sod or following certain other grasses, and there are wire-worms and white grubs that attack cultivated crops when they are put in after grass or other infested plants. Of course this means bad farm practice from the standpoint of the entomologist; but not until quite recently have the farmers been willing to consider any modification merely because it would produce conditions less favorable to insect increase.

Besides those species devouring foliage above ground, there is a large subterranean population of wire-worms, white grubs, maggots, slugs, and the like that attacks

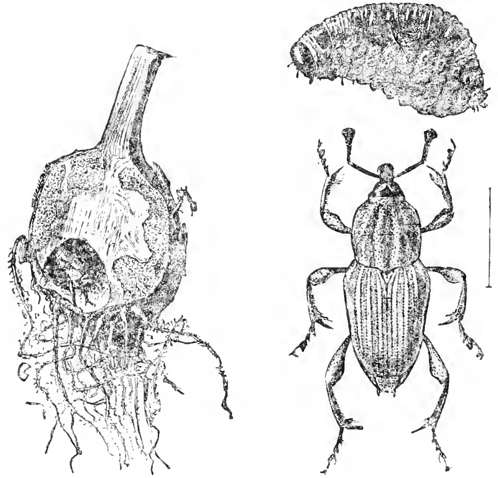

FIG. 119.—A bill-bug, its larva and work in root of *Scirpus*.

the roots of plants. The underground work of plant lice has been already mentioned; the species now referred to are those that actually devour the root tissue or dig into the underground stem so as to destroy or weaken the overground plant. Cabbage, onion, radish and other root maggots, wire-worms, grub-worms, grape-root worms, root-borers—all are familiar terms to the farmer, and represent sources of injury that he has learned to dread.

And when his plants have developed well, his fruits have set and all looks fair and free from any of the pests already enumerated, the farmer is by no means certain that he will get either seed or fruit. There are numerous midges that develop in the ovaries of fruits and flowers, and either feed directly in the seed or suck its juices so as to shrivel it. We have species that attack the kernels of wheat, rye, oats, sorghum and other grains; others that get into the ovaries of the clover flower and destroy the seed—so thoroughly, indeed, that in some localities, while it is easy to get good crops of clover hay, it is impossible to get any seed at all. Midge larvæ, indeed, are found under the most divergent conditions and their injuries are by no means appreciated as yet to their full extent. Not that the midges are alone in this work, for among the beetles there are a large number that infest special crops. There are, for instance, the *Bruchidæ*, containing the bean and pea weevils that infest seeds of all sorts of legumes, from the pods of the locust tree to those of the lentil. Sometimes only a single larva develops in a seed as is the rule in peas, or there may be up to half a dozen or more in a single bean. And the worst of it is not the infestation that comes in the field alone, but the likelihood that without great care it may be brought and continued in the barn or storehouse. Even after harvest the wheat is not safe, for if it be left in shocks in the field, the Angoumois grain moth is apt to find it and start its work of destruction.

Further, among the snout beetles we have species that confine their attacks to the buds or developing seed capsules. The boll-weevil of the cotton is perhaps the most conspicuous example, and this species alone has demanded the expenditure of hundreds of thousands of dollars in its study and attempted control, and has injured the value of the crops in the affected states by many times that amount. Less conspicuous but equally destructive on a smaller area is the strawberry weevil, which develops in the bud, preventing the formation of fruit.

This habit of placing the eggs in a protected position or with reference to the food supply of the larva is quite a trick among the snout beetles, and some of their habits are very interesting as well as economically important. The nut-weevils have the snouts very much elongated and very slender so that they are enabled to pierce the growing burr or husk and place the egg in the developing nut, long before there is a shell to be reckoned with. The plum curculio cuts a little flap from the surface of the fruits that it infests and in this bit of loosened tissue lays its egg, safe from the pressure that might otherwise be exerted upon it by the growing fruit. And so it is with other of the *Rhynchophora* that attack our fuits, large and small.

Even tree fruits are not exempt from midge attack, one form depositing its eggs in the pear bud that the young larvæ may be in position to get down into the seed capsule while yet the passage-way into the ovary is wide open. Other flies attack growing fruits of many descriptions and are furnished with a horny ovipositor of considerable length for puncturing the skin. Apple, orange, olive and plum, all have their "fruit-flies" that demand toll of varying importance.

Among the *Lepidoptera*, none is better known than the codling moth, the larva of which feeds in apple, pear and quince. Where no active measures are taken for its control, it is no unusual matter to find from 90 per cent. to 95 per cent. of all the fruit on a tree wormy and of inferior value. This species seems to be distributed wherever the apple is grown. Other species attack grapes in a similar manner and there are feeders among the smaller caterpillars in or on almost every fruit that grows. Besides feeding on or in the fruits, many of them are also miners in leaves and even in twigs and branches. There is, of course, a great deal of

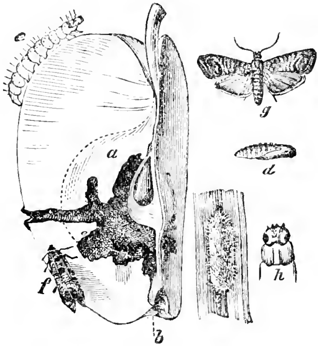


FIG. 120.—Codling moth and its work: *a*, the injury done; *b*, place where egg was laid; *c*, larva; *d*, pupa; *i*, cocoon; *f*, *g*, adults.

difference between the amount of injury caused and usually a species is confined to either one kind of plant or to the members of one plant family. There are a few, however, that are obnoxious to a variety of crops and none that occurs to me at present is much worse than the corn-worm, boll-worm or tomato-worm, as it is variously named. It winters, usually in the pupal stage, underground, and early in the season emerges as a yellowish, inconspicuous owlet moth, which during the month of May in the middle states seeks a place to lay its eggs. At this time the most attractive things seem to be the early peas, and very soon the greenish caterpillars will be found boring into the forming pods. As the young corn makes its appearance this becomes attractive to the moths of the second brood, and the caterpillars, now usually with a pale reddish-gray tinge,

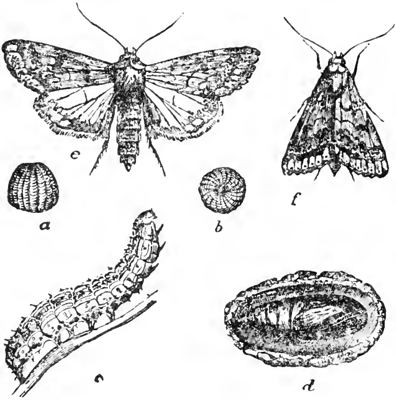


FIG. 121.—*Heliothis armiger: a, b,* eggs; *c,* larva, ("corn-worm", "boll-worm", and "tomato-worm"); *d,* pupa in cell; *e, f,* moths.

appear as stalk-borers. As the sweet corn advances the caterpillars find the forming ears, and many a barren stalk is so because the ear has been eaten even before it appeared between the leaves. About this time, too, the earliest tomatoes become of nice size and offer another outlet for the caterpillars, which bore into the fruits when they are nearly ready to color and take those specimens which would otherwise have sold for fancy prices. In the southern states the cotton at this time begins to offer an attraction in the shape of forming buds, and a little later the "boll-worm" makes its appearance. When corn is plenty, that forms an attraction superior to everything else and then come the "corn-worms" so common and objectionable in the "roasting ears." Sometimes there is only one, usually of good size; sometimes there are several, usually smaller, and the explanation is that the insects are very pugnacious and when they meet they fight. When there are two or more full grown larvæ in one ear, it simply means that they have never chanced to meet. The caterpillars continue in the corn until it is cut and stacked, and some may yet be found at husking time; but from the time the kernels begin to harden they go underground as they mature and change to that pupal stage in which they safely pass the winter. After they once get started in spring they can be found almost continuously in some one or the other of their food plants.

There remains yet one more way in which growing crops are attacked and that is by borers, and these also are of many kinds and all sizes. The stalk of wheat and the fruit tree fifty years old are equally subject to this kind of injury, and larvæ of *Coleoptera*, *Lepidoptera*, *Hymenoptera* and *Diptera* all contribute to the mischief.

Some of these stem feeders really do not deserve the name of borers at all, as for instance the larva of the Hessian fly, which attacks wheat stalks at the base and produces a gall that checks growth, or the joint-worm which works into the stem at a joint; but for convenience we may class as borers all forms which feed out of sight in stems, twigs, branches or trunks. And it is astonishing what a variety of borers there are and how generally plants are infested. Not cultivated plants only, but arrant weeds like burdock, thistle, rag-weed and the like. We find among Dipterous larvæ maggots in some variety, often producing swellings or galls in herbaceous stems, besides the numerous midge larvæ already so often mentioned. Hymenopterous borers are comparatively few in number and chiefly members of the saw-fly or horn-tail divisions. Some of these are in grasses including grains, and are slender, white, caterpillar-like forms which often hollow out the entire length of a stalk. Pithy stems like those of blackberry and raspberry are favorites with this kind of borers, not many of which belong to the seriously injurious class. The horn-tails attack woody plants more generally, but are also comparatively few in number, both as to species and specimens.

Lepidopterous or caterpillar borers we have in great variety and in all kinds of plants and trees. The largest of them belong to the Cossids and Hepialids, the giants among the so-called Microlepidoptera. Most of these are confined to forest trees, and it is notable that our only really troublesome species is an imported one—the wood-leopard moth—that attacks shade and orchard trees. In this connection it is interesting to observe that the boring habit among *Lepidoptera* is an ancient one, not even confined to terrestrial vegetation, and that by far the greatest number of the borers of the present day are members of the simpler and earlier types of Microlepidoptera.

Wood-feeders largely we find in the Sesiid clear-wing moths, among which are some of our most troublesome species, *e.g.*, the peach borer, cherry borer, currant borer, blackberry borer and the like. Some live in the solid wood of trunks and branches, like the cherry borer and those that live in oak, maple and other trees: some live just beneath the bark and make chambers rather than galleries, like the peach borers: others are in roots like the blackberry crown borer and the grape root borer; while yet others feed in the centre of a stem, like the currant borer or lilac borer. Among the Pyralid moths there are numerous borers in herbaceous plants and among the Noctuid or owlet moths there is quite a series in which the boring habit is well developed; such plants as potatoes, tomatoes, corn and wheat being among the victims. A few are twig borers on trees, like those working in the terminal shoots of peach and plum.

It is among the *Coleoptera* or beetles that boring habits are especially well developed. There is almost no sort of tree or plant among our cultivated species that is not more or less infested by coleopterous borers of some kind, and in a very general way that same assertion might be made of all trees and plants. So general is this habit that except in the predatory and scavenger forms, there is scarcely a series that does not have some sort of boring species included in one or more of its families. The Longicorns and Buprestids are almost all borers in woody tissue; among the Rhynchophora or snout beetles there are numerous borers in herbaceous plants and a goodly representation that works in woody tissue. Apple, pear, quince, peach, plum, nut and citrus trees are all more or less subject to attack, and grape, blackberry and other vine and small fruits are equally apt to be infested. Potatoes have weevil borers in the stem, many grasses have similar borers in the roots, and even cabbage has its leaves and stem more or less riddled. Among the tree borers there are two rather well-marked types represented by the round-headed and flat-headed borers. The former quite usually do most of their work in solid tissue, the latter are more apt to make channels in the bast or between bark and sap-wood, getting into the solid wood only to pupate. Some of the round-headed borers have similar habits but on the whole they are more diverse in their methods of feeding than the flat-headed borers. With both we have species that attack only dead or dying tissue, and others that will feed in or on perfectly healthy trees. Some of them must have matters just exactly right, like the twig-girdler which lays an egg and then girdles the twig below the point of oviposition, so that in the first high wind it may break off and fall to the ground. Others like the oak-pruner demand living wood as food for the larva, but a dead twig for pupation; so the larva girdles the twig from the inside, leaving only a thin shell, makes itself comfortable beyond this point, and waits the time when it is blown to the ground to complete its transformations.

Another important series contains the bark beetles which, while they do not so much affect the horticulturist, do most seriously affect the forester and the lumberman. It would hardly pay to go at much greater length into the different kinds of borers, because the fact of general infestation has been sufficiently brought out.

We see from this brief review that from the time the plants first show above ground until the harvest is in, they are subject to the attacks of sucking and chewing insects in all their parts, and that neither root, stem, leaf, fruit nor seed is free from liability to infestation and injury. Some of this liability is increased by injudicious farm practice, some of it is the consequence of past carelessness, and a portion is due to the inevitable change in the balance of nature caused by culture and by planting large areas in one sort of vegetation.

It follows that the agriculturist and horticulturist is always at war with insects, either actively or passively, and he always suffers some injury, large or small in proportion to the activity of his campaign against them. What is not always realized by the passive resistant is that what he loses is all profit. It costs about so much to prepare, plant and harvest an acre of corn, wheat, potatoes, cabbage or other crop, and if the insects eat 10 per cent. of what would have been produced had they been destroyed, that 10 per cent. is directly out of the farmer's pocket. And if in two orchards of the same variety, producing exactly the same number of barrels of apples, those from the one are clean as the result of an active campaign and the latter gnarled and wormy from curculio and codling moth, the difference in price between the fancy fruit selling at the top of the market, and the other fit only for the cider mill, is the measure of loss, since the cost of handling and growing is practically identical.

It has been attempted again and again to calculate and estimate the annual loss of agricultural products due to insect ravages in the United States and Canada, and no one has fixed it in figures of less than hundreds of millions. As a matter of fact, the money loss is difficult of estimation, because any material addition to the amount of a crop might have a decided influence on its price. It is not uncommon, for instance, for a farmer to make more money on a short crop than out of an excessive one, and this factor has been previously noted by Dr. L. O. Howard, in his discussion of the same subject. A better basis, perhaps, is the percentage of crop destroyed, and that has been estimated at anywhere from 10 per cent. to 25 per cent. of the total. The careful student will be inclined to consider the 10 per cent. estimate too low; it is doubtful whether, in actual lessening of crop, it will reach the 25 per cent. mark; but if we take into consideration the lessened value of much of the crop actually harvested and marketed, I believe that 20 per cent. depreciation in value of farm products is not too high an estimate of the losses annually caused by insects in the United States and Canada. As the value of such products was estimated in the Report of the U. S. Department of Agriculture for 1907 at $7,412,000,000, the estimated loss, due to insect ravages in the United States alone should be put at $1,500,000,000 at least.

## CHAPTER XII

### THE WAR ON INSECTS

Having detailed the character of the injury done by insects and given some idea of its extent, the question arises; what can we do to prevent such loss, and what has been done in this direction? There is yet, in the older settled portions of our country a rather widely distributed feeling that as insects exist and feed on plants, they were created for that purpose and that it is meddling with a divine institution to attempt their destruction or limit the amount of injury done. It is the same sort of spirit that protests that "it can't be done" whenever any attempt is made to better sanitary conditions, to control the spread of disease or to limit the agencies that make for the spread of infection. Supplemented by the equally wide-spread conviction that any grown man that engaged in so trifling an occupation as the collection and study of insects must of necessity be deficient in intellect or of unsound mind, this condition was responsible for retarding the development of economic entomology to the middle of the last century, and even then it developed slowly and failed of general appreciation.

With the establishment of agricultural experiment stations under the Hatch Act of 1887 conditions began to change. Entomologists were appointed in several of them; their work began to make itself felt, its importance began to be appreciated, and now there is scarcely a state or territory in which there is not at least one working economic entomologist. In 1889 an Association of Economic Entomologists was formed with about a dozen members. In 1907 there were enrolled among the active and associated members, most of them in official positions, no less than 211 names; and that does not include all of them. Of foreign associates interested in the same line of work there are forty-five, and that includes most of those in official positions. In 1888 there were less than half a dozen makers of pumps or machinery suitable for insecticide work, while nozzles were difficult to obtain and poor. At present there are numerous makers of machinery and each of them presents a long line of pumps, nozzles and fittings for applying insecticides and fungicides. On the Pacific Coast the problems were somewhat different from those of the Atlantic Coast and the line of development in the production of insecticides and spraying machinery was also different. Fumigation with hydrocyanic acid gas, the lime and sulphur and resin-washes are Pacific Coast contributions; the development of the arsenical sprays and the mineral oil preparations are to be credited to the Atlantic Coast, or at least to the territory east of the Rocky Mountains, for much of the pioneer work with insecticides was done in Illinois and Missouri, by Walsh and Riley.

In 1889, every ounce of kerosene emulsion was home-made, and Paris green, London purple, hellebore, tobacco and pyrethrum were practically the only insecticides on the market. There was whale oil soap also, but expensive and an unknown quantity as to its ingredients. Now there are a large number of manufacturers throughout the country, producing commercially every preparation that has proved useful in the hands of experimenters, and chemists everywhere are seeking to improve and cheapen the known combinations or to devise new and more effective ones. Miscible oils and lime and sulphur combinations are made and shipped in car-load lots, while arsenate of lead, absolutely unknown as an insecticide in 1888, is sold in ton lots to individual purchasers.

This development in the face of at least passive opposition could not have taken place in so short a time as twenty years had it not been promptly demonstrated that the fight was a paying one. And when the reader who remembers the fruit markets of that earlier period, compares them with the magnificent productions in our markets at present, he will realize the advance that has been made. Farming and fruit growing has been developed as a science, along scientific lines. The soil is a chemical laboratory, with elements ready to be combined into organic compounds under proper conditions. The plants produced in this soil and from these elements serve naturally as food for man and other animals, including insects. Man wishes to get it all for his own use and, of course, therefore desires to eliminate the insects as partners. Can he do it, and if so, how?

To the first part of the question we answer yes, to a very great extent; to the second there is a less definite answer since every group of species must be dealt with according to its kind and no one application will serve for all kinds of species. Often, indeed, where insecticides cannot be used at all, we can circumvent by planting at proper times, rotating crops so as to prevent undue increase, and by harvesting so as to destroy the insects before they mature. In the garden and in the greenhouse where conditions are more under our control, injury from insects can be reduced to a minimum, and the records from our orchards show that wormy fruits are not necessary features in a crop.

We have learned that as against practically all insects that chew their food and feed openly upon plant tissues, arsenical preparations may be used with good effect. Up to within a few years Paris green was practically the only satisfactory material of that character, and even that could not be used on tender foliage or on conifers without extreme caution. Recently, the manufacture of arsenate of lead has been developed to a point that we have now a satisfactory killing agent that can be safely used at any strength on foliage of any kind. It has the further advantages of remaining well in suspension without constant stirring, and of sticking to the foliage indefinitely after it has once dried. In the garden and greenhouse no other stomach poison should be used and it will be found effective against all caterpillars, saw-fly slugs, beetles and their larvæ and generally against insects that actually eat foliage; it is useless against sucking insects such as plant lice, scales, plant bugs and the like. It contains less actual arsenic than Paris green and at least three times as much must be used to obtain the same results. One pound in 10 gallons of water will kill potato beetles and their larvæ; 1 pound in 50 gallons of water will kill slugs and small caterpillars; 1 pound in 25 gallons of water is a good general strength for ordinary caterpillars and other similar species. Paris green is perhaps a little more economical in orchard work and can be used at the rate of 1 pound in 50 gallons of water for potato beetles, 1 pound in 125 gallons for orchard work and 1 pound in 150 gallons on sensitive foliage or against young caterpillars. It should never be used on peach or conifers and should be very cautiously used in the garden. It is well to slack one pound of quick-lime with every pound of Paris green to combine all the water-soluble arsenic in the insecticide, especially when used at the greater strengths.

Arsenate of lead comes in paste form only, at present writing, and cannot be applied dry.* Paris green can be mixed with air-slacked lime or dry hydrate and applied with a bellows, and for cases where a powdery dusting will form as satisfactory a coating as a spray, the application in that manner is just as good. There are cases, however, as where an insect feeds only on the underside of a leaf, where a dust does not and cannot cover as well as a spray, and others where the material must be forcefully applied so as to get into a crevice or cavity in order to secure a maximum effect.

There are preparations of white arsenic which can be made at home, forming combinations with lime which are stronger and cheaper than either Paris green or arsenate of lead; but these are dangerous in unskilled hands and require so much care in preparation that they are not advised, save when very large quantities of material are needed.

It is very often desirable to combine an insecticide and a fungicide so as to prevent injury from disease as well as insects, and Bordeaux mixture is the fungicide generally used with either Paris green or arsenate of lead. This Bordeaux mixture is in itself very offensive to many insects and some of the flea beetles will scarcely touch a plant protected by it. If the arsenical insecticide is added to the fungicide in the same proportion as if it were water, an extremely effective material is obtained. The Bordeaux mixture is prepared as follows:

| | |
|---|---|
| Copper sulphate | 4 pounds |
| Quick-lime, stone or shell, good quality | 4 pounds |
| Water | 50 gallons |

Dissolve the copper sulphate in one gallon of hot water, slack the lime in water sufficient to do it well, and strain. These are the stock mixtures and will

* A dry powder has been produced, but is still in the experimental stage.

keep a long time if tightly covered. To prepare for use dilute each of the stock mixtures with ten gallons of water, combine them in a barrel of sufficient size, and then add water to make up the full amount. Never combine the concentrated stock mixtures as it produces a heavy coarse precipitate that is much less effective. The above mixture is the full strength that is reasonably safe for general use. The tendency is to use only three pounds of copper instead of four on orchard trees, and on peach it should be even weaker, if used at all.

Against plant lice, scale insects and other sucking insects our battery is much larger, much less satisfactory, and applications must be much more carefully made. We can spray a tree with arsenate of lead to reach an insect which we expect will make its appearance to-morrow; but a contact insecticide must be applied when the insects are actually present and must be brought into actual touch with the specimen before it can be effective.

Contact poisons kill either by direct corrosive action on the skin of the insect, as where dry hydrate of lime is dusted on a soft slug, or by clogging or entering the body through the spiracles or breathing pores. Soap mixtures clog by forming a film over the openings and matting up the hairy guards that as a rule protect them; a soap that makes a rather thick slimy suds is therefore preferable to one that forms a clean, thin suds. Mineral oils are very penetrating and kill by getting into the body cavity through all openings. Decoctions like those of tobacco and hellebore get into the spiracles and perhaps also through the mouth into the stomach and set up a convulsive affection that results in death. Dry powders like hellebore and tobacco are effective in proportion as they are finely ground, and even fine road dust has some insecticide value. The fine dust particles get into the trachea and there set up specific irritation, but they must get there to do any good at all. Coarse particles are no better than so much coarse dust and insects with covered spiracles are not affected at all. It is quite possible, therefore, to have an insecticide which is very effective against one series of a species, but which, against another series, will be entirely useless: any material for which it is claimed that it will kill everything, should for this reason be looked upon with distrust from the start.

Plant lice are among the most common of all the insects to be dealt with in a practical way, because there is almost no vegetation not more or less infested by them. In a small way on house plants, insect powder, *i.e.*, pyrethrum, is the cleanest and simplest remedy. It can be dusted on through a sieve, put on with a little powder puff or bellows, or it can be made into a decoction or tea, using an ounce to two quarts of hot water. This can be put on with an atomizer and, when fresh, it is very effective against all kinds of plant lice, against most small caterpillars and slugs, and against the larvæ of scale insects. It loses strength rapidly when exposed to the air, and in corked bottles the decoction ferments and moulds after a day or two. It is altogether too expensive for general use in fields, but in gardens or greenhouses its cleanliness and absolute safety to plants are in its favor.

Tobacco has a much greater range of usefulness. When very finely powdered it may be dusted on and will kill about the same sorts of insects as the pyrethrum. It may be worked into the soil of pots and benches to kill root lice, besides discouraging many other underground insects. It is also a fertilizer and stimulates the plants to which it is applied. If a spray is preferred, one pound of chopped tobacco stems may be boiled in one gallon of water until a dark brown extract is obtained, and this will control white fly, mealy bugs and most of the other greenhouse pests, provided it be frequently and thoroughly applied. It stains delicate flowers and is apt to cause a little injury to very delicate foliage, but in general it is safe on all ordinary plants. The cost of tobacco dust or ground tobacco is low enough to warrant its use in gardens and fields, and we have no better remedy for root lice on trees and plants; even the woolly apple louse succumbs to a liberal application. To reach such insects, the soil must be removed to a depth of at least six inches in a circle from eighteen to twenty-four inches around the trunk, varying according to the size of the tree, before a layer of ground tobacco is put on, and the trench must be then filled up. The soil moisture and rains extract the nicotine and bring it into contact with the root lice. Stems, whole or coarsely chopped, are of very little use, since the nicotine is extracted so slowly as to be ineffective. Tobacco is also used in greenhouses as a fumigant and is quite effective against a great variety of pests. It may be burnt on a layer of hot coal in an open stove, an extract may be smeared on the pipes for slow evaporation, or paper-rolls soaked in the extract may be burnt on wires suspended in different parts of the house. And that brings up the point that there are now on the market commercial extracts under various names which, when only small quantities are to be used, are cheaper and better than can be made at home. They must, however, as a rule be used at greater strength than recommended on the labels in order to be thoroughly effective.

Soaps are also used against plant lice and other sucking insects and these have a much greater range of effectiveness than the extracts just mentioned because of their greater penetrating power. All soaps have some insecticide value, and so washing the leaves of house plants with soapsuds is always good practice provided the suds be not too strong. An ounce of soap to one quart of water is ordinarily quite sufficient to kill green lice and young scales, especially if whale oil soap is used. At twice that strength it kills even the more resistant forms of plant lice, but becomes dangerous on tender plant foliage. While soapsuds may be freely used on house plants, the suds should not be allowed to accumulate on the surface of the soil for the alkali may easily become detrimental to the plant roots. For greenhouse and garden use, whale oil soap is much improved by an addition of tobacco and such a combination is now obtainable from most seedsmen.

In the field, whale oil soap is much used against plant lice, and is effective at varying strengths depending on the insects to be reached. Against most green lice 1 pound to 4 or even 6 gallons of water may be satisfactory; against brown or black Aphids twice that strength may be required, and against young scales 1 pound in 2 gallons is the weakest mixture that can be effectively used. For winter work against armored scales like the San José, 2 pounds in 1 gallon of water are applied.

In all dealings with plant lice and similar insects that multiply rapidly, prompt action is essential for best results. It is sometimes easy to destroy a slight infestation and to get rid of a few specimens on leaves or stems. If they are allowed to multiply unchecked until the plant begins to show signs of suffering, it will be necessary to make much more thorough treatments, and as many species tend to curl or otherwise to distort the leaves, hiding in the shelter thus caused, it becomes also more difficult to reach them. It must always be remembered that no contact poison can be effective unless it actually touches the insect aimed at, and covering the top of a leaf no matter how thoroughly, when the insects are feeding on the underside, is of little or no use. More ill success results from a failure to recognize this fact, than from any deficiency in the material applied.

There are a large number of "patented" or proprietary insecticides on the market for killing plant lice, scales and similar insects, and some of these are really meritorious; but they are usually expensive and, in the long run, no better than the materials we have just enumerated.

While it is comparatively easy to reach and control plant lice on most ordinary farm crops and in the garden, it is decidedly more difficult to reach scales whether soft or armored, and even mealy bugs are difficult to kill, in spite of the fact that they are comparatively unprotected.

There is only one period in the life of such insects when they are within reach of mild applications and that is when the young have just hatched and are moving about without protective covering. Theoretically that is the best time to reach them and with some species it is practically the only time. The oyster shell scales and some others that attack our trees and shrubs winter in the egg stage under the mother scale, practically safe from all our known mixtures. Early in the season, depending of course on latitude as to the exact time, these eggs hatch, all at about the same time, so that for two or three days there is a great swarm of naked larvæ, and for a week there are newly set scales with the thinnest sort of protective covering; that is the time for whale oil soap, kerosene emulsion, miscible oils or whatever else is depended upon to reach the insects. After the scale has once hardened, none of our summer applications that are safe on foliage can be relied upon to kill. A large number of scales, soft as well as armored, come under this general rule as to development and treatment, and the gardener or farmer who has insects of this kind to deal with, should know their life cycle sufficiently well to know when to make his applications.

Scales that bear living young usually winter in the partly grown condition and may be reached by applications which either penetrate through or under the protective covering to the insect beneath. When reproduction begins the larvæ are born singly, a few each day, and this may continue for two or even three weeks. By the time the last young emerge, the earliest are already well grown and covered with scales, so there is no time when a single application will reach more than a small proportion of the infestation. If sprayings could be made every third day so long as reproduction continues, satisfactory results could be gotten; but while this may be feasible in the garden and greenhouse, it is not practical in the field and orchard. In large greenhouses this method is often resorted to and the scales on palms and other hot-house plants are kept under control by frequent application of weak material.

In the orchard much more drastic measures must be resorted to, and in winter when the plants are dormant, very caustic or very penetrating materials are used. For caustics nothing is much better or more generally effective than the lime and sulphur wash, formed by combining one pound of ground or flowers of sulphur with one pound of unslacked stone or shell lime in three gallons of water. This combination is made by boiling the lime and sulphur with just enough water to do it properly and afterward diluting to spraying strength. It usually requires about one hour's boiling to get the proper combination and, when reduced with warm water and applied fresh on peach and plum trees, there is no more effective remedy against the pernicious or San José scale. The material is, of course, quite as effective a killing agent on other trees as well; but on pear and apple it is more difficult to reach all the specimens in their hiding places behind or under bud or bark scales, in crevices or, in the case of apples, among the hairy clothing of the terminal shoots. On such trees the wash should be applied with great force and as thin as possible so as to aid its penetration. On peach, plum and apricot trees it exercises also a beneficial effect in checking certain fungus diseases and improving the general health of the tree. On trees in foliage this wash should never be used, nor on conifers of any kind. As to the practical work of making the wash, place the lime and the sulphur in an iron kettle over a brisk fire, pour in hot water enough to cover and start slacking, which will bring the mass to the boiling point at once. Add hot water slowly, stirring to prevent burning and to facilitate the combination of lime and sulphur. One part of good lime is a little more than enough to combine one part equal in weight of sulphur and any excess of lime remains as whitewash and adds nothing to the effectiveness of the material. If the lime is poor, a little more should be used to make sure that all the sulphur is combined. If flowers of sulphur are used, three-quarters of an hour's boiling is sufficient if hot water is used as a starter. Otherwise an hour is better. If ground sulphur is used boil half an hour longer.

Where large quantities of the wash are to be made up, live steam is quite generally used, and the mixture is made in barrels into which live steam is led from a central boiler. These plants vary so greatly that only the principles upon which they are built can be stated. In all cases there is a drop from an elevated steam pipe, reaching to the bottom of the barrel, where there are usually cross arms of perforated iron pipe to permit the steam to get to all parts of the mass and prevent irregular cooking. The proper amounts of lime, sulphur and water are put into the barrel, and the steam is turned on for an hour or longer, until the combination is completed.

It is also possible to make a good combination of lime and sulphur by the heat of slacking lime alone, or by using potash in addition to the lime to produce the proper degree of heat. It requires heat to combine the lime and sulphur and it matters little whence this heat comes; whether from burning wood or coal, from steam, or from slacking lime, soda or potash. The wash is effective in proportion to the completeness of the combination and the thoroughness of the application.

To make the lime, soda and sulphur combination put into a barrel 22 pounds of best quality stone lime and add hot water enough to start slacking. While this is in progress sift in 10 pounds of flowers of sulphur, stirring and adding hot water as needed until the mass is well reduced. Then add 11 pounds more of lime with more hot water, and sift in 7 pounds more of sulphur while this is slacking. Before it is done steaming, stir in 1½ pounds of caustic soda which will cause a violent boiling, and when this begins to subside add an equal amount and then again another 1½ pounds, making 4½ pounds altogether. Keep stirring and adding hot water slowly until the combination is completed. Then add hot water to make 50 gallons and apply at once.

To make the self-boiled lime and sulphur combination, place forty pounds of best quality stone lime in a barrel, sifting in twenty pounds of sulphur flowers with it so that it is well mingled. Add boiling water enough to start a brisk slacking and cover with a heavy blanket to confine the heat. Add hot water as needed to keep up the slacking, and stir occasionally to aid the combination. Keep this up until the lime is fully reduced and mixed with the sulphur. Then let the combination stand covered for an hour to maintain its heat, after which hot water enough to make fifty gallons should be added.

The objection to these mixtures is that unless they are very carefully made there will be a considerable percentage of uncombined sulphur which is of no value, and there is so great an excess of lime forming whitewash, that it makes the wash too thick to get into crevices or through plant hairs. But even this wash is now made commercially and there are several brands on the market which, when thinned down for use, cost very little more than the home-made wash, and much less to the man who has no plant available for making up small quantities. Some of these brands have been tried in comparison with the home-made wash and, when reduced no more than nine times, they were quite as effective. The gardener who has only a few trees to be treated will save time and money by using the commercial preparations.

This wash is extremely caustic and corrosive. Machines in which it has been used should be thoroughly washed out and oiled before being put away, the hands should be protected by gloves while spraying, the face should have a coating of vaseline, and if there is much wind the eyes should be guarded by goggles.

As already indicated this wash was developed on the Pacific coast, and it is undoubtedly more uniformly effective there than it is on the Atlantic coast. A variety of reasons for this difference have been suggested, but for our purpose it is enough to recognize that the fact exists.

Sulphur by itself is not a mean insecticide if we stretch the term insect just a little so as to include the mites. In the greenhouse, against red-spider there is nothing much better than flowers of sulphur dusted on the surface, where the slow decomposition generates fumes that are fatal to the mites and not conducive to the multiplication of other parasitic organisms. In the citrus orchards of Florida a similar practice is adopted to prevent injury from the rust mite; lump or ground sulphur is used, and here the hot, moist atmosphere favors effects that are unobtainable in the dry climate of the Pacific Coast regions.

A barrel half full of lump sulphur set in a warm corner of the greenhouse and kept filled with water is an excellent spraying solution for general use on the benches. There is very little sulphur in the solution, but there is enough to keep down mites, check mildew and destroy many other spores of disease organisms. As the water is used, more is added, so that half a barrel of sulphur may last a year or more. It needs a warm corner to start decomposition.

Combined in a soap, sulphur is used as a wash for mangy animals, and as true mange is due to a mite, good effects are obtained. Better yet are the results when sulphur is administered internally. It is one of the materials eliminated through the skin, and is therefore brought into direct contact with the skin parasites.

Among the penetrants the mineral oils rank highest. A light crude petroleum of the paraffine series, testing 43° or over on the Beaumé scale, will penetrate and kill every scale it touches, and it spreads so well that it will get under every protection, into every crevice and through every covering of plant hairs. Unfortunately it goes further and, if carelessly used, is just as likely to get through the outer bark into the bast, and to kill the tree as well as the insect. Nevertheless the material has been and is even yet quite extensively used, and is the reliance of a large number of good fruit-growers. I do not advise its general use, but mention it for the benefit of those willing to try it. In the garden and conservatory it has no place.

Kerosene is a derivative from the crude petroleum, with the lighter volatile oils, the vaseline and the paraffine eliminated. It can be safely applied to trees even when in full foliage, in a very fine spray, under conditions which favor rapid evaporation. I have frequently applied it with excellent effect late in summer on very scaly trees, killing off most of the insects without appreciable harm to the tree itself. Apple and pear trees are most resistant to the mineral oils; peach and other stone fruits are most susceptible. Citrus trees stand kerosene very well under favorable conditions; but on the whole this is another material which needs a thorough appreciation of all the factors involved to make it safe. As a winter application it is not nearly so effective as crude oil because it evaporates so much more completely, leaving nothing in the way of a coating to continue its work; but that very feature makes it safer to use.

The good points of kerosene as an insecticide were long ago recognized, and nearly thirty years ago methods of emulsifying it with milk and afterward with soap were worked out under the direction of Dr. C. V. Riley then U. S. entomologist, by Mr. H. G. Hubbard. The milk formula was soon abandoned; but the soap emulsion stands to this very day, much the same as Mr. Hubbard worked it out.

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| Kerosene | 2 gallons |
| Water | 1 gallon |
| Hard soap | ½ pound |

Shave the soap fine and dissolve in boiling water; warm the kerosene and add to the boiling suds; churn with a force pump by pumping back into the pail through a fine nozzle until a thick white cream is formed. This hardens into a butter-like mass when cold and may be diluted to any desired extent with water. If both kerosene and suds are hot, five minutes' churning will bring the proper combination. In making and diluting the emulsion, soft water should be used and only a little water should be mixed in at first to get the butter into soluble form. A well-made emulsion will keep for weeks in a dark cool place; but eventually the oil will separate and come to the top.

Diluted with from twelve to fifteen times its own bulk of water this is an excellent summer remedy for plant lice, young leaf-hoppers, mites, thrips and other insects liable to be killed by contact poisons. The penetrating qualities of the oil and clogging effect of the soap are combined; but the soap prevents the rapid evaporation of the kerosene, holds it longer in actual contact with the vegetation to which it is applied, and thereby increases its danger. Most plants will stand an application of 1 to 15; few plants will safely stand anything stronger than 1 to 10, and 1 to 12 is the more usual limit. As a summer wash against scale larvæ the 1 to 10 mixture is an excellent combination on all save stone fruits, and even 1 to 15 must be carefully used on such. For winter work it is not advised, because at a dilution strong enough to kill scales, it is actually more dangerous to the trees than the undiluted oil itself. Nevertheless, kerosene emulsion shares with whale oil soap the burden of the fight against plant lice, with the advantage of cost in favor of the emulsion.

A more recent development in the use of petroleum oils is found in the miscible or "soluble" oils, sold under special names such as "Scalecide," "Kill-O-Scale," "San-U-Zay," or simply as "soluble petroleum." These are preparations of petroleum, crude or partly refined, so combined with vegetable or animal oils, rosin oil and sulphonated oil, as to be readily miscible in water to any extent, forming a perfectly homogeneous spraying mixture of even effectiveness throughout. None of these oils contain over 75 per cent. actual petroleum and few contain over 10 per cent. of water, which is actually necessary to form the emulsion. They are, therefore, approximately equal in their effect and are extremely useful as winter washes against scales hibernating in the partly grown condition. Against the pernicious or San José scale a dilution with fifteen parts of water is the weakest mixture that should be used in general practice. Good results have been obtained with a solution of 20 to 1, under exceptional circumstances; but I would rather recommend a dilution of only twelve times if I were anxious to secure definite effects. These oils have no vaseline or paraffine residue, hence can be safely applied for successive years, even peach showing no appreciable injury within my experience. It is on large old apple and pear trees that these miscible oils find their most effective field of use, for they spread and penetrate well and when applied with proper force can be made to reach wherever a scale can go. This quality makes them effective against such species as the pear psylla, which hibernate as adults in crevices and under rough bark scales, and against such mites as hibernate under bud scales or in similar positions. They are not especially effective against insect eggs, and have little fungicidal value. In all cases where the oils and the lime and sulphur are equally effective, the latter is preferable because of its influence on plant diseases. "Soluble" oils are not safe as summer washes at effective strengths, although when carefully applied on mature foliage of hardy trees, no serious injury is caused.

Miscible oils can be made at home and formulas have been published minutely describing the process; but it requires skill, absolutely uniform materials and an outfit that only the user of large quantities can afford. Furthermore it is an unpleasant and even somewhat dangerous process which can hardly be recommended to ordinary farmers and fruit-growers, and certainly not to gardeners using only a few gallons or even barrels.

There is another field for kerosene emulsion and the like when it is necessary to reach certain leaf-miners which, while feeding on plant tissue are never exposed to the action of arsenical coverings, but live entirely in the leaf tissue. There is usually, however, an opening to the surface, or the tissue above the mine is so thin as to be readily penetrated by the oil; hence a contact insecticide against a leaf-miner is indicated.

It is with the mineral oils as with the lime and sulphur; the effects are not equally satisfactory under all climatic conditions. Applications that are entirely safe in one locality may be distinctly injurious to plants in another, and a little caution must be observed when the material is used for the first time in localities differing from those in which it has been tested.

Another combination with both caustic and penetrating qualities as well as a specific feature of its own is found in the resin washes which have had a wide use on the Pacific coast, but have not been much exploited in the east. Two formulas for summer and winter washes are given:

SUMMER FORMULA.

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| Resin | 20 pounds |
| Caustic soda, 70 per cent. or over | 5 pounds |
| Fish oil | 3 pints |
| Water sufficient to make | 100 gallons |

WINTER FORMULA.

| | |
|---|---|
| Resin | 30 pounds |
| Caustic soda, 70 per cent. or over | 9 pounds |
| Fish oil | 4½ pints |
| Water sufficient to make | 100 gallons |

These are really very thin varnishes, readily soluble in water and therefore more effective in a dry climate. The second or winter wash contains so much resin that its application to foliage would choke and thus destroy it and is also much more caustic. The summer wash is effective against scale larvæ, recent sets, plant lice and similar species, clogging their spiracles.

To make these washes, boil all the ingredients together with about twenty gallons of water until thoroughly dissolved, adding hot water from time to time as needed, but never enough to stop the boiling after it has once begun. Three hours will be required for a complete mixture, hot water being gradually added to make up fifty gallons, stirring continuously. After this, the balance of the 100 gallons may be added in cold water. It may be that the work of preparing these washes has something to do with their present lack of popularity.

It frequently happens that we have underground insects such as root maggots to deal with, and none of the soap or petroleum washes heretofore considered is of any value in this direction. The petroleum mixtures, indeed, usually kill the plants primarily and the maggots consequentially. We derive some help from carbolic acid emulsified with soap, so as to be soluble in water. To make this, dissolve one pound of hard soap shaved fine, in one gallon of boiling water, add one pint of crude carbolic acid (50 per cent.), and churn the whole into an emulsion with a force pump. This emulsion is diluted for use with thirty times its own bulk of water, and applied to the soil at the base of infested plants. The mixture, to be effective, must come into direct contact with the insects, hence the earlier it is applied when cabbages and onions are infested, the more effective it will be; there must be enough material to penetrate down to the lowest point reached by the maggots. On cabbages this may be three or even four inches and may require half a pint of material; on onions it would not be over an inch or two, and would of course require much less. Wireworms and white grubs are also affected by this emulsion and driven away or killed. On growing foliage it cannot be safely applied, and it is unsuitable for use against maggots infesting radishes or beets.

Carbolic acid is sometimes used to increase the effectiveness of whale oil soap and an ounce of the acid in a gallon of spray mixture does improve it to some extent, but not enough to balance the extra cost and labor of working it in. It has been added to air-slacked lime for use as a repellent around melon and other cucurbit vines to keep off the melon beetles. It forms an ingredient in tree washes and preparations intended to prevent the entrance of borers, and is somewhat effective in this direction. But insects are not often adversely affected by unpleasant odors unless they are also directly poisonous.

Another use that has been proposed for the acid is to paint a band around the trunks of fruit trees with the idea that it would be absorbed by the bark and carried into the circulation, poisoning the sap to such an extent as to kill all the scales and other insects feeding on the tree. The theory is a very plausible one at first sight, but unfortunately the acid as it penetrates strikes first the down-current that carries it to the roots, and when there is enough of it to get into the active cells, these promptly die and refuse to do any carrying. If the acid gets still further and really does strike the up-current, then the girdling is complete and the tree itself dies. Rarely, however, is there enough acid applied to cause this mischief.

This suggests the fact that there are always a number of philanthropic gentlemen ready to aid the farmer —for a consideration—and willing to insert into his trees a compound of which they only possess the secret, which will infallibly kill all the insects infesting the tree and cure all its diseases. They are even willing to give a written guarantee to that effect. Many a farmer and tree owner even in cities and towns falls victim to the persuasiveness of these benefactors, who bore holes two inches deep into the wood, fill them with their compound and fasten it in tightly with a wooden plug, absolutely beyond reach of those cells of the tree engaged in carrying sap. Even were the material soluble and active, it is imbedded in tissue which serves only as a support to the tree, and has absolutely nothing to do with its nourishment. Its absorption into the surrounding cells would therefore mean precisely as much as if it were absorbed into the tissues of the nearest fence or hitching post.

Caustic potash and caustic soda have a limited use on the farm, but in the orchard and garden are frequently used as winter washes for tree trunks. In a solution of one pound in one gallon of water we have a mixture which kills lichens and mosses on tree trunks as well as many spores of fungi, and leaves the bark in a nice, clean, shining condition, vigorous and free from all clogging organisms. It is astonishing what an improvement a wash of this kind will often produce on fruit and shade trees, and where a clean healthy bark is a *desideratum*, there is no better way to obtain it. Besides cleaning the bark, this material will also corrode and destroy many of the thinner scales such as the species of *Chionaspis* of which the scurfy scale is an example. That species hibernates in the egg state, and the egg is not affected by the caustic; but the scale covering is thin, easily corroded, and the eggs are then washed out and scattered by rains. Those larvæ that hatch from them will rarely be able to find their way back to the tree, and in most instances the eggs themselves perish under the unnatural conditions. A material so caustic as this should be carefully handled, for sores caused by it frequently ulcerate badly and heal very slowly, because of the destruction of tissue.

Lime is one of the most useful materials on the farm from a great many points of view. Few insects care to rest voluntarily on a lime-covered surface; only hunger will induce most species to eat through it, and some will not touch it under any circumstances. Lime in its various forms is about the only material used by most European orchardists, and whitewashed trees form a characteristic feature in many localities. As a whitewash on fences and farm buildings generally, inside and out, it covers over or fills crevices and cavities that would otherwise serve as hiding places for insects. It seals up and destroys the eggs of such insects as may be present when the wash is applied, and on tree trunks it prevents the setting of young scales. A continuous coat of whitewash will absolutely prevent the setting of all scales and will keep many of them from hatching; but it requires rather a thick coating to effect this, for the lifting of the scales when the young are ready to emerge, will usually break the coating. In chicken-houses the wash should be applied with a spray pump so as to force it into cracks and crevices, and the addition of a little carbolic acid is here a distinct gain to the wash. The same may be said of it in stables and out-buildings generally. Instead of the crude carbolic acid, which is not readily soluble or miscible with watery liquids, one of the many soluble tar or cresol preparations may be used in liberal quantities. Tree trunks are often white-washed to prevent borers from entering, and with good effect so long as the coating is thick and well put on. But the egg-laying instinct is among the strongest, and the parent beetles of round, flat-headed and bark borers will hunt for a broken point, an unfilled crevice or a loosened bark scale, to find a place where they can safely deposit an egg, while the clear-wing moths will lay their eggs anyway, and trust the minute caterpillar to find a bare place or a crevice through which entrance may be obtained to the sap-wood below.

On foliage, whitewash is not an advisable application; its brittle character makes it quickly imperfect, even where the tissue itself is not harmed.

In its dry condition the range of usefulness of lime is much greater. Air-slacked lime mixed with Paris green for application through a blower or powder bellows is well known, and as a driver in fields of cucurbs invaded by the cucumber beetles, it is relied upon in many parts of the country. As a dry hydrate, that is slacked with just enough water to crumble it into a dry powder, it is useful against a great variety of viscid or moist slugs, like those of the asparagus, potato, pear and the like. When slacked in this way the fine particles of lime are still very caustic and need another particle of water to complete the slacking. If, in this condition, the lime is dusted on the moist slugs, each particle of lime gets the desired particle of water from the body of the slug, and in doing so burns a little hole into the skin. The effectiveness of a dry lime application, therefore, depends on the moist condition of the insect to be dealt with, and in consequence early morning applications when there is a little dew are always most effective. In the asparagus fields where once the slugs have gotten a start after the cutting season is over, there is nothing better than a cloud of dry hydrate of lime put on with a powder gun just at sunrise or a little before.

This reference to the time of application in order to reach the insects in the best condition brings to mind that there are some plants and insects that by reason of a waxy or powdery surface or covering repel or shed water particles. The woolly lice and mealy bugs are insect examples and the cabbage leaves are good plant examples. When cabbage plants are attacked by Aphids which have a covering of fine waxy powder, ordinary watery applications are of little or no use, and even soap washes or kerosene emulsions must be applied with considerable force and in a fine spray to really wet and be effective. When on cabbage or similar plants arsenical applications are required, the matter becomes even more difficult and some sort of adhesive is needed. Molasses, glucose and soap add materially to the sticking qualities of arsenical sprays other than arsenate of lead; but in extreme cases a resin soap is needed. Such resin soap may be purchased, or may be made up according to the following formula:

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| Pulverized resin | 5 pounds |
| Concentrated lye | 1 pound |
| Fish oil | 1 pint |
| Water | 5 gallons |

Boil resin and oil in one gallon of water until the resin is thoroughly softened, then dissolve and add the lye slowly, stirring continuously until thoroughly mixed. Then add four gallons of water and boil for about two hours or until you get a clear amber-colored liquid which dissolves readily in cold water. This liquid resin soap may be added at the rate of one gallon to every 100 gallons of any arsenical spraying mixture other than arsenate of lead, or at the rate of one gallon for every fifty gallons of any spray used on cabbage or similar waxy leaves. The adhesive should be placed in the entire amount of water to be used and, when thoroughly dissolved, the Paris green or other poison should be added.

Powdered white hellebore was at one time almost the main reliance against saw-fly larvæ such as the currant worm, and is even yet the favorite for this purpose with many gardeners. It may be applied as a dry powder, pure or mixed with two or three times its own weight of cheap flour; or it may be used in the form of a decoction, using one ounce, steeped in two quarts of hot water. This is also effective against certain small caterpillars and naked slugs, but is not so reliable and is more expensive than some of the other materials already recommended.

Sometimes we can make use of certain abnormal tastes among insects to secure their destruction. Thus cut-worms prefer wheat bran to their normal food, and will eat it by choice even when a corn plant grows near by. We take advantage of this habit by making up a mixture of white arsenic one pound, to wheat bran seventy-five pounds; mingle thoroughly, moisten with sugar water enough to make a soft mush and put a spoonful in the hill of plants to be protected. There will be dead cut-worms next morning, and no further cutting of plants. Sometimes, where a field of grass has been plowed down and cut-worms are known to be present, rows of the dry bran and arsenate mixture are drilled at ten-foot intervals across the field to attract and destroy the worms before the crop is set out or is up, as the case may be. Paris green may be used instead of arsenic, but the latter is cheaper. Chickens or other farm animals liable to eat this poisoned bran should of course be kept out of fields so treated.

Grasshoppers of certain injurious species have an abnormal fondness for moist horse manure and great numbers can be killed off by mixing one pound of arsenic with three gallons of droppings and spreading where the insects are most numerous. It is better to use small quantities several days in succession than large quantities at one time, because as the material dries out it loses its attraction.

To keep borers out of fruit and shade trees, all sorts of mechanical protections have been devised. The use of lime-wash has been already referred to, and that is most wide-spread. Sometimes soap, carbolic acid and arsenic are added, and help a little toward its effectiveness, because the poison may kill the parent beetles when cutting a place for the egg, or the young larvæ when attempting to enter. Sometimes the entire trunk is cased in wire mosquito netting held at a distance of at least half an inch from the bark at all points, and sometimes only the lower portion of the trunk is so protected. The round-headed borers of pomaceous fruits like apple and quince, and the boring caterpillars infesting peach and its allies, usually enter near the surface and work in just at or below the ground. A wash of hydraulic cement mixed with water, or better, with milk, is often used to protect trees at this point and on peach trees a band of newspaper or tar paper is tied so as to extend a little below the surface and for a distance of eighteen inches above. Other mixtures have been recommended and all are more or less effective. It means simply coating the bark with anything that the insects cannot or will not penetrate in their efforts to get to their place of feeding.

Gas tar is safely used in some localities as a protection, but in others is fatal to the trees, and it is better not to use tar paper or any black paper, since that seems to cause a scalding of the bark beneath it. So, while paints mixed with linseed oil are tolerably safe, those in which turpentine is used should be avoided, as they are almost always dangerous.

A great variety of protective devices are in use on trees to prevent insects from getting up or down the trunk, or to attract them as shelter for larvæ and pupæ, and some of these are effective in special cases, as when a band of fluffy cotton or of a sticky material bars the ascent of female canker-worm moths or the ascent of caterpillars of the tussock moths, from egg masses laid below them. The larvæ of codling moths can be attracted to burlap bands when they leave the fruits to pupate, and many of them can be there gathered and destroyed. Finally, on field crops we can use, very effectively, tar paper discs to protect cabbage plants from root maggots.

The direct campaign with poisons is a most important feature of the war with insects, and to carry it on we need a great variety of machinery for applying powders and liquids, and such machinery is now obtainable almost throughout the civilized world, to meet the needs of the man who wishes to protect one plant as well as of him who farms ten thousand acres. There is every range from the little atomizer to the steam pump, and from the little powder bellows to the rotary fan blower capable of enveloping a large tree in a dust cloud. Specific description of such machinery would be of little avail, and he who has the selection need keep in mind only a few fundamental points. The apparatus should be so simple as to be fully understood by the purchaser; it should be well made and of the most durable material; it should be more than equal to the utmost demands ever made on it: it should be able to give great force to the material issuing from spout or nozzle, and there should be a nozzle or spout capable of bringing the dust or liquid into actual contact with all the insects to be reached, under all the circumstances under which they occur. Thoroughness of application is always essential to success, and careless work is always wasteful and expensive work.

We are not confined in our work to insecticides merely. Modifications of the primitive method of collecting potato beetles in tin pans with a scum of kerosene are still in use, and in some cases form our only practical line of offense. Leaf-hoppers and grasshoppers are collected by means of hopper-dozers drawn by man or horse power over infested fields, gathering up the insects on a bed of soft tar or petroleum. We have similar contrivances to run under grape vines into which we jar rose-chafers, and wheeled, umbrella-like structures to capture plum curculios. In a few cases when large, conspicuous caterpillars like those of the hawk-moths infest low plants like tobacco or tomatoes, hand picking is the best and most reliable method.

So, when borers get into our peach trees, the only really effective way is to go after them with a knife, and if apple or similar round-headed borers are in fault, a soft wire is added to the outfit to reach such insects as have gotten into the heart wood.

Against species that march we erect barriers of one kind or another. Army-worms and chinch-bugs, for instance, may sometimes be stopped by running a ditch across their path or a couple of plowed furrows with steep sides to prevent their easy ascent. At intervals in these furrows post holes are driven and as the insects crawl along the bottom of the furrow or ditch seeking a way out, they fall into the post holes and are treated to a dose of kerosene. Myriads of specimens are often killed off in such campaigns, and the farmer saves his crops, without perceptibly decreasing the number of his foes for the year to come.

Some species we are able to circumvent by a little adaptation of our farm practice. For instance, where corn is raised continuously on the same land in the middle west, the corn-root worm soon becomes a serious pest; but if every third year the land is put into some other crop, no harm ensues because the insects in the old cornfields are starved out. We have learned that rotation of crops is a good thing, and try to avoid planting two successive crops of a similar kind; or if that cannot be avoided, planting or plowing so as to avoid harm. For instance, corn following old timothy is bad practice where the latter is liable to be infested with bill-bugs. Corn belongs with the grasses, and the bill-bugs finding no timothy when they emerge, attack the corn. If the succession cannot be avoided, the soil should be plowed in fall and the corn planted as late as may be. Similar practice is to be followed where root web-worms occur and, as a rule, old sod is better fall-plowed if insect injury to the next following crop is to be avoided. Most wire-worms and white grubs require two entire years to come to their full growth, pupating or even changing to an adult in the late fall of the second year, and coming out as adults during the spring of the third. Fall plowing at the end of the second year will expose these pupæ or recent adults and kill them, whereas if delayed until the land is fit the spring following, the beetles would be sufficiently mature to survive.

The corn-worm and many similar pests also pupate in the fall, making cells in which they lie safely in all ordinary winters. Fall-plowing breaks up those cells and brings the soil into direct contact with the pupæ, which are killed by the contractions and expansions of the soil about them, under the influence of frost and thaw. Of course fall-plowing is not always good farm practice from other points of view, and the grower must decide what he had better do after balancing all the factors of his problem. But in the control of underground pests this practice is important. Sometimes, indeed, our efforts are indirect, as when in late fall we plow land infested with root-lice very deeply, to destroy the nests of the ants that shelter them or their eggs during the winter.

Frequently the time of planting or the time or manner of harvesting determines the question of injury. We have learned that in regions subject to Hessian fly attacks, late-sown wheat may be almost entirely free from infestation, while that sown early may be almost totally destroyed. This is because the early fall rains bring the adult flies to maturity and they lay their eggs on wheat or other grasses very soon thereafter. Anything that comes up later is exempt from attack. It is impossible to fix an arbitrary date, for that varies with latitude, and even in the same latitude the time at which the flies appear on the wing is determined by weather conditions: a drought may delay them until the very latest period for safe sowing has passed, and in that case early and late sown are apt to be equally infested. Sweet potato growers in regions infested by flea beetles have learned that if they delay setting out their plants until the middle of June they have little to fear from the insects; but if plants are set in May, they are almost certain to be seriously injured. Other cases might be cited, but it is sufficient to show that by a careful study of the habits of a species we can often avoid injury without a direct fight. Wheat harvested in July and left in shock is very likely to become infested by the Angoumois grain moth. Carted from shock to mow the infestation spreads until, in September or October when threshing time comes round, a large percentage of grain is defective and "flies" or "moth" are numerous. If instead of being left in the fields and then mowed, the grain had been at once threshed and binned, there might have been a little surface infestation, but there could have been no serious spread in the bulked grain.

Occasionally an insect can be diverted from a more to a less valuable crop, as in the case of the squash borer which prefers late squashes like the hubbard or marrowfats when it can get them, but will accept summer varieties like the crook-neck if the others are not present in equal attractiveness. The grower therefore plants crook-necks early, and on the same ground puts in the other varieties late. The early vigorous growers attract the moths, the plants become infested but are vigorous enough to produce a crop that pays for the labor, before the late varieties need the ground and the borers approach full size. Then the infested plants are taken out and destroyed, borers and all, leaving the others free with prospects for only a very small brood of moths for next season.

That introduces the matter of clean culture. It has been shown, elsewhere, that some of our well-known pests pass a portion of their life, and sometimes an important one, on wild plants allied to the crop grown, and these serve to tide it over from one season to another. Clean cultivation rids the farm or garden of these wild plants and makes it more difficult for them to survive. So a great many species live through the winter on the remnants of the crop they infested, and were these destroyed, the hibernating forms would be destroyed with them. It is a good general rule, when you are done with a crop, get it off as soon as possible and burn all left-overs that might shelter injurious insects. Stems of cotton, cucurbs, potatoes and tomatoes are among those with insects so controllable.

If in all orchards all dropped fruit could be kept picked up and destroyed, injury from codling moth would be at once reduced more than one-half; plum curculios would soon cease to be important, and fruit flies would lessen materially. Some work is done along this line in large orchards, but as a rule the insects in dropped fruits are allowed to develop at will.

Farm animals can be utilized much more extensively than they have been. Sheep and hogs in an orchard are great helps in disposing of dropped fruits and of such insects as come to the surface. A drove of hogs in a sod field infested with wire-worms and grubs will tear it up and dispose of a very large number of the specimens if aided by a few shallow furrows to give them a start. Chickens, turkeys and guineas are great insect feeders and can be trained to follow the plow and pick up every specimen brought to view. Once a small number of fowls has been trained to this work, the flock will continue the training; the new members following the older without additional trouble to the farmer.

In the selection of fertilizers considerable benefit is sometimes derived in the use of minerals rather than barn-yard manure. Many insects require the shelter or presence of decaying vegetable material, and do not thrive in soils impregnated with mineral fertilizers. This is a point, however, where the question of farm practice is eminently one for the cultivator, and no general recommendations can be given.

There are still among our battery of insecticides the gases and vapors, and these are of great importance. Sulphur fumes have been used for many years against household insects but these are being superseded by the hydrocyanic acid already described.

Bisulphide of carbon is a clean, water-white liquid, very foul in smell, volatilizing rather slowly at ordinary temperatures, the vapor heavier than air and very inflammable. This vapor is fatal to most insects exposed to it in a confined space for an hour or more, and it destroys the vitality of seed germs exposed to it much over twenty-four hours. It is rarely used in the field, but for insects infesting stored products is extremely useful. Where entire plants infested by plant lice can be covered by a tight cone, jar or box, one drachm or, roughly speaking, a tablespoonful to every cubic foot of space will kill the insects in one hour. In melon or cucumber fields in which plant lice have just made a start, it is sometimes possible to check their spread by treating the infested hills under hay-caps or similar covers, or even under tubs or large pails. Large clam-shells make good receptacles for the liquid, and as the vapor is heavy, the shell should be put on top of the mass of vines.

A much more usual employment for the material is to destroy insects infesting seeds like peas, beans, lentils, wheat or corn. In such cases the infested seeds should be put into a tight box or other receptacle, and bisulphide at the rate of one drachm per cubic foot of space should be placed in a shallow dish on top of the mass, the box or jar being tightly covered, of course. In twenty-four hours all the insects will be killed without injury to the germinating power, but if the seed is to be used for planting, it must then be aired out before being again put away. Eggs are not killed by this vapor, hence it may be necessary to treat a second time in case of badly infested material. If the grain or other seed is to be used for food only, it may be kept covered indefinitely, as no injury is caused to its milling or cooking qualities. In large spaces one pound may be counted for 100 cubic feet of space, or for one ton of binned grain. Shallow vessels should always be used for evaporating dishes to expose as large a surface as possible, and the heavy nature of the fumes must be taken into consideration. Under no circumstances should the material be used near a light of any kind, and if the person using it has any regard for his safety, he will not smoke while handling it even in the field.

Before the development of the hydrocyanic acid gas, bisulphide of carbon was used to treat even large spaces like houses, barns and mills; but its cost and dangers are so great compared with the newer material that it is not now employed in this way. Purchased in small quantities at drug store prices, this is rather an expensive material; but there is a special much cheaper grade known as "Fuma" bisulphide, which answers every purpose for agricultural use.

Hydrocyanic acid gas is produced by the action of dilute sulphuric acid on cyanide of potassium, and is intensely poisonous to all animal life. It effects vegetable life to a somewhat less extent and more slowly, so that there is usually a fair margin of safety between its effectiveness on insects and the danger of injury on plants. For the destruction of insects on dormant nursery stock, and for the treatment of rooms and buildings to destroy household or other pests, the following formula answers for 100 cubic feet of space:

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| Cyanide of potassium, 90% pure (by weight)... | 1 ounce |
| Sulphuric acid, sp. gr. 1.83 (by measure)....... | 2 ounces |
| Water.................................... | 4 ounces |

The gas is lighter than air and is generated in an earthenware jar, pot or basin as follows: First pour in the water, add the acid slowly, and finally drop in the cyanide broken into small lumps in a thin paper bag. The order of mixing is important, for if the water be poured into the acid, the amount of heat suddenly developed will be so great as to spatter the material in every direction. The cyanide is dropped in, bag and all, to somewhat delay the development of gas and permit the operator to escape or close the fumigating chamber. The method of dealing with household pests has already been given. Greenhouse fumigation forms a study by itself, because of the difference in effect on the many sensitive plants there raised, and for which no generally applicable directions can be given.

Orchard fumigation is not much practised in the east where most of the trees have a dormant season permitting their treatment with sprays. On the Pacific coast, fumigation of citrus and olive trees is quite largely practised and elaborate apparatus for covering trees with gas-tight tents is in use. But even there the practice is not yet finally settled, and an extensive series of experiments is in progress to determine the most effective methods. Under these circumstances no more is needed here than a reference to the matter, emphasizing its extent and importance.

By no means all the materials used in the fight against insects have been enumerated here; a few, like gasoline and *Delphinium* are of very limited application and have been referred to in other connections. But enough has been said to show the chief weapons in our battle with the tiny foes that influence us so much more than is generally known. What is not told is the number of materials and combinations that have been tried and rejected, before those here enumerated were fully tested out and approved. In the reports and bulletins of agricultural departments and experiment stations, almost every year brings records of trials made of new combinations; some originated by the experimenters, some produced by inventors or manufacturers who believed they had discovered something better than was ever known before. Out of all these experiments very little is annually added to our battery; but the limitations of the older materials are becoming ever better understood and the number of effective combinations is larger now than ever before.

And so in the machinery for applying insecticides and fungicides there is an enormous and continuing progress. A collection of dusters and sprayers dating only ten years back now seems antiquated and ineffective, and as our methods of application become perfected, the benefits derivable increase.

From the practical standpoint man now carries on his war against insects absolutely without regard to the natural checks of that insect, if it be a native. If it be an introduced species his attempt is to restore the natural balance by introducing the natural checks as well, and beyond that he relies on his own efforts.

We have learned to take advantage of the weak points in the life cycle of a troublesome species, and we know that there is at least as much in the proper application of insecticides as in the insecticides themselves. As there is a continuous specialization in the raising of crops, so each grower learns to deal with the pests of that crop by experiment and observation.

It is beginning to be realized that numbers of specimens are not a measure of the difficulty in dealing with pests. Mosquitoes are abundant enough in examples, but their life cycle is simple and the methods of control are obvious. The old cry "it can't be done" has not even yet ceased, in the face of the results obtained in Cuba, Panama, and New Jersey. And yet, after all, it is simply a matter of dealing with many breeding places in the same way, and when a problem is reduced to a mere matter of amount, it is a matter of time and dollars only to get it done.

Flies are even more universally distributed than mosquitoes, and from the sanitary standpoint yet more dangerous; but even they will not escape man's efforts at control. The campaign has been already begun and no doubt it will be continued until practical measures for checking fly development are universal.

To one in the forefront of the battle progress sometimes seems distressingly slow, and results small out of all proportion to the efforts made; but, after all, a review extending back a decade or two shows that neither the entomologist nor those for whom he has labored need be ashamed of the advances made. At all events the importance of insects in their relation to man has come to be fully realized.

# INDEX

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