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THE CLASSIFICATION OF INSECTS AND THEIR RELATION TO AGRICULTURE.

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ENTOMOLOGY.

There is a constant and rapidly increasing demand from farmers, horticulturists and others more or less directly interested in insects, or more frequently in the ravages and losses caused by them, for a bulletin giving in a condensed form such information as is required to fight our tiny foes in an intelligent manner. Information of this kind in a printed form is of more utility than any number of letters that might be written, since the illustrations necessary to describe clearly any insect can not well be given in a letter.

When we consider the immense numbers of insects that exist in all parts of the habitable globe the task, to give in a few printed pages even an outline of their classification, seems to be a more than futile effort. Moreover, any classification of this multitude of forms (one million species of existing insects is not an exaggerated estimate) must be a more or less artificial one, and it is therefore best to only attempt one of such insects as are known to occur in our own state.

Geologists speak of the age of shells, of fishes, of reptiles, periods all passed long ago, and they might well call the present geological age the age of insects, because these animals outnumber all others combined. In fact insects are found in every part of the globe that man has ever been able to reach, with the exception of the oceans, where they are replaced by closely allied animals, the crustaceans. And yet, notwithstanding the abundance of insects and their almost omnipresence, how few persons are really able to give a definition of an insect? The term *insect* is derived from two latin words *in* and *seco—cut into*, because the body is *insected* or divided into rings. At one time this term was applied to the entire group of articulates or jointed animals, and consequently early writers spoke of "six-legged," "eight-legged," "many-legged" insects. Articulates or jointed animals, which by persons not familiar with zoology are frequently called insects are: Wood-lice or Tow-bugs, Mites and Ticks, Spiders, Harvest-men, Book-scorpions, True-scorpions, Centipedes, Thousand-legs and others not found in Minnesota. A glance at the illustrations (Fig, 1 to 6) will show that none of these animals possess the essential characters of true insects as defined below.

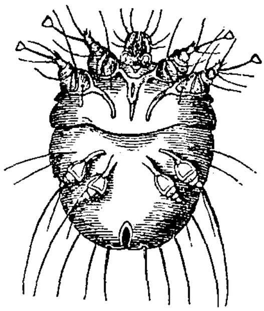

Fig. 1. Female Itch-mite of man, enlarged 80 times.

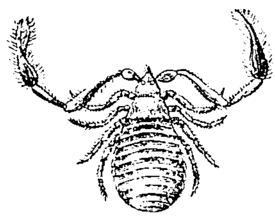

Fig. 3. Book-scorpion, greatly enlarged.

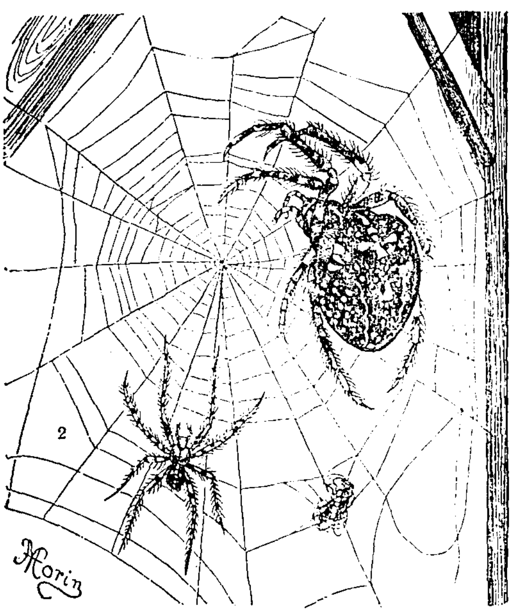

Fig. 2. Male (2) and female of Diadem-spider. Natural size.

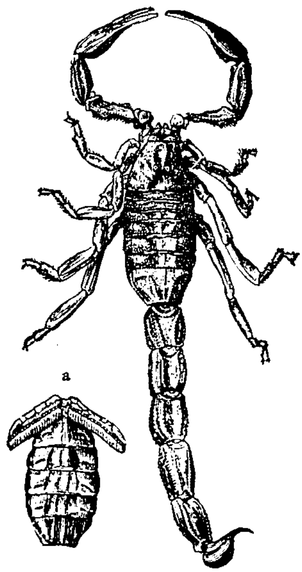

Fig. 4. Scorpion. Nat size.

At the present time we use the term INSECT only for those articulates that possess six legs, and that have their external skeleton apparently composed of thirteen joints or rings, which are grouped into three regions, viz: the *head*, *thorax* and *abdomen*. (See Fig. 7.) The true insects, or *hexapoda*, (six-feet) undergo a more or less complete metamorphosis, possess in the adult stage wings, and breathe through a peculiar respiratory system with external openings termed *spiracles*. All insects are developed from eggs, with a few apparent exceptions; plant lice, for instance, reproduce both by eggs and by budding. The body of an adult insect is divided into three regions, each with peculiar functions. The *head* contains the organs of vision (compound eyes and simple eyes), the jointed antennæ or feelers, which are the principal organs of touch, smell and hearing, and the mouth-parts, organs of taste and feeding. The *thorax* contains the organs of locomotion—the three pairs of

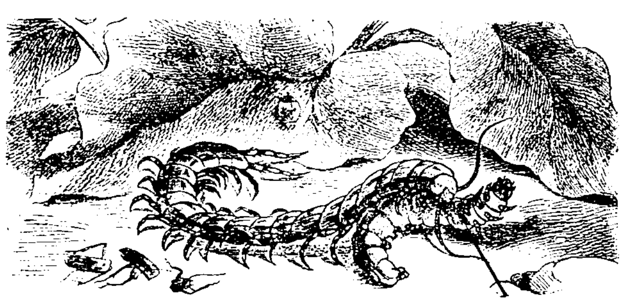

Fig. 5. Centipede. One-half size.

legs and two pairs of wings: The *abdomen* contains the organs of digestion, reproduction and often of defense. All insects pass through a number of transformations or metamorpho-

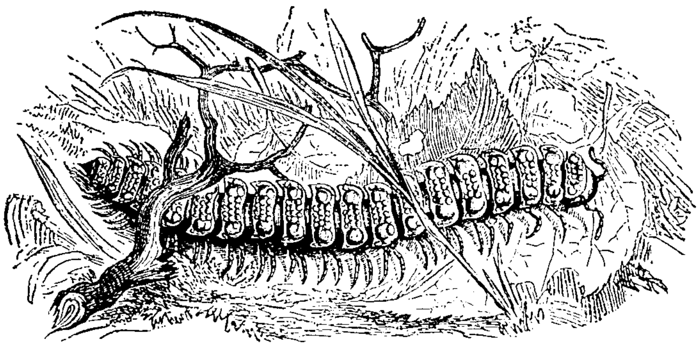

Fig. 6. Thousand-leg. Enlarged.

ses before reaching the adult or winged and sexual stage. The first of the four principal stages is the *egg*. In most cases this is deposited by the female upon the proper food,

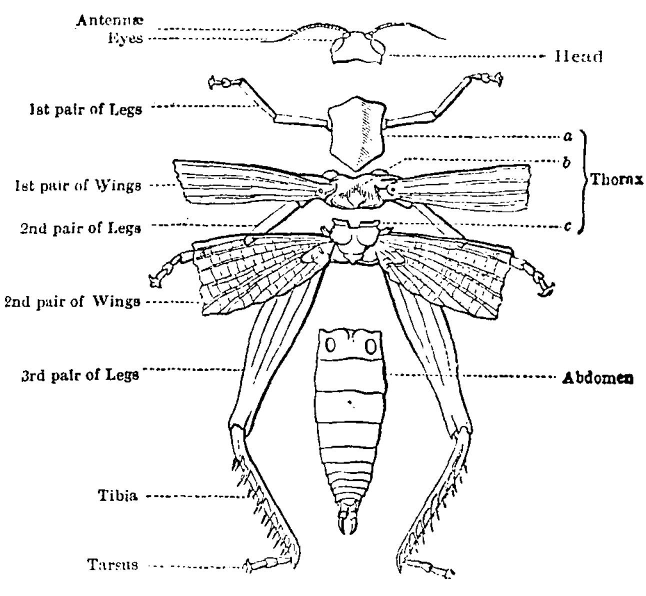

Fig. 7. A Locust or "grasshopper" dissected to show divisions of body.

and is there left to hatch without any further maternal care. In social insects, such as bees, ants, etc., the eggs are taken care of by various methods. In exceptional cases the egg is retained in the oviduct until ready to hatch, or even until it has hatched. The *larva* (caterpillar, worm, maggot, slug, grub, etc.,) hatches from the egg, and it is in this stage of the life of an insect that most growth is made. But as the external skeleton of an insect does not grow the space within soon becomes too small, and the larva has to throw off this old shell and replace it by a new and more commodious one. This action of throwing off the old shell is called *moulting*, and the process has to be repeated a number of times before the larva reaches its full size. During the larval existence of an insect there is stored up all the material required to produce wings and organs of reproduction, as well as to transform the other organs, as eyes, legs, etc., into their final shape. When fully grown, the larva is transformed into the third stage, or *pupa* (chrysalis, nymph). In this stage the insect is usually quiescent, at least apparently so, though in reality it is a very active stage, as the most wonderful changes have to take place inside the stiff and rigid pupal shell, and frequently within a very short period. After a certain time the skin of the pupa breaks open, and the fourth and final stage or *imago* appears, ready to perform all the functions of a winged, sexual insect. Although these transformations seem to be very sudden, they are really nothing but continuous growth, arrested at intervals by the inflexibility of the outer skeleton. The metamorphoses of insects vary very much, and serve as the basis for separating all insects into two groups, those with a *complete* metamorphosis, as described above, and those with an *incomplete* one. A *complete* metamorphosis is one of the most wonderful transformations known to natural history. From an egg hatches a worm-like creature, always hungry, growing rapidly until its full size is attained, when it suddenly stops feeding, and changing to an apparently lifeless object, becomes a pupa. Remaining almost motionless in this condition it breaks open and gives forth a much larger being, possessing many organs not found before in the earlier stages, and able to fly about to mate and deposit again eggs. In a complete metamorphosis the different stages such as egg, larva, pupa and imago do not resemble each other at all. In an *incomplete* metamorphosis we have no such notable changes of form. The egg hatches into a being that looks very much like the parent, being of course quite small, and lacking all traces of wings or sexual organs. This larva feeds just as ravenously, and has in consequence of its rapid growth also to moult a number of times, and during these slight changes in size it acquires gradually rudimentary wings, which increase in size until the adult stage has been reached. But during this whole period of growth no quiescent state like that of a true pupa appears, and the young insect resembles its parent throughout the period of growth. Butterflies are a good illustration of a complete metamorphosis, and locusts of an incomplete.

Illustrations of a complete metamorphosis are given in Fig. 8, 10, 19, 26, 33, 34, 46, 49, 50, 51, 54, 55, 58, 76, 78, and of an incomplete one in Fig. 61, 66, 67, 80.

The mouth-parts of insects give us also an excellent means for classifying them into three groups. One group possesses a *biting* and *sucking* mouth; the second one contains insects which chew their food by means of a pair of horny jaws acting in a horizontal direction; the third group possesses apparently no jaws, and the species belonging here are *sucking* insects. They obtain their food by piercing and sucking by means of four bristles enclosed in a jointed beak, or fluid food by means of a long and flexible tongue.

But why is it at all necessary to classify insects for any practical purpose? In reply it must be stated that we can not fight against injurious insects with any hope of success if we do not know their structure. For instance, an insect that has no mouth to bite or chew can not be poisoned, and the application of any arsenical insecticides would in most cases be perfectly useless. Nor is it enough to know the structure of the insects; we must also know their habits and transformations, because this knowledge alone will enable us to apply the remedies at the proper time. In fact, notwithstanding the great progress made in economic entomology during the last ten years, we are only able to combat successfully a limited number of injurious insects by means of insecticides. A large number of others, and the most injurious ones at that, can not be reached in that manner. Time, labor and material to do so successfully would cost much more than the whole crop would be worth. The chinch-bug, locusts, cut-worms and others, if very abundant, can not be fought successfully by means of insecticides. Yet this is no reason why we should not be able to reduce their ravages to a minimum. But without being perfectly familiar with the habits of these insects, with their life-history in all and every detail, including their insect and plant foes, we can not hope to succeed. But by knowing all this we may be able to discover a weak spot into which a wedge can be driven to break up their ranks. Only by attacking the weak spot of a well fortified castle is victory possible.

When we consider the immense numbers of insects, and the fact that they devour every and all kinds of organized matter, it seems almost vain even to try to fight against them. All insects are not, however, enemies to man; on the contrary, the great majority are either indifferent to him, or are either directly or indirectly beneficial. The indifferent ones eat substances we can not or do not use; the beneficial ones eat noxious plants, or decaying substances, thus purifying the air and making space for other living organisms. Without them the soil would be covered with dead vegetable matter, the now existing plants, i. e., those that are fertilized by the wind, would become smaller and smaller, because their seeds, not eaten by insects, would all have an opportunity to grow, thus crowding, dwarfing and killing each other. Without insects the great majority of our brightly colored flowers would not produce seeds, as most of them are dependent upon the work of these animals to cause cross-fertilization.

The question is frequently asked: "Why is it that farmers, horticulturists, gardeners, etc., are more troubled in the United States with noxious insects than they are elsewhere?" or "Why is it that more injurious insects and of different kinds are found now than formerly?" The reasons for this increase of insects, both in numbers and kinds, are not so very difficult to give. In Minnesota, when settlements were few and widely scattered, the whole country was covered with its virginal vegetation. Plants and animals were adapted to each other, and as soon as one of them became for any reasons exceedingly numerous, natural checks in the form of enemies to such plants or animals soon reduced them to their normal numbers. In a state of nature plants distribute themselves in such a manner that one kind never occupies the ground exclusively. Our native forests are not composed of one species of trees, but of very many kinds, in constantly varying proportions which depend upon the character of the soil and the needs of the different kinds of trees. The same is true of the plants that clothe our beautiful prairies. Notwithstanding the uniformity of the soil the prairies are covered here and there with different plants. Animals, and chiefly insects, depending directly or indirectly upon plants, naturally follow their distribution. When the sod of our prairies was broken to receive the seeds of plants not grown there before, the soil responded freely to the new demands and yielded phenomenal crops. This prospective reward for agricultural toil soon attracted more and more farmers until the prairies were teeming with human beings, eager to mine the golden grains—the only form of mining that will make a people really happy and prosperous. But in cultivating more and more soil, man destroyed the finely balanced relation between the animal and vegetable kingdoms by adding a disturbing factor. At first but few destructive insects to the new crops were found, because they had to be introduced from elsewhere; but as soon as they found this Eldorado—an immense area covered with the best kind of food for them—they were not slow to appropriate to themselves what was not planted for them. Insects of all kinds, but at first mainly injurious ones, will invariably take possession of fields where plants of one kind are grown upon a large scale. Insect foes of such plants will soon find their way to such fields and fix there a new home. In course of time, however, things will change for the better, simply because the foes of such newly introduced species will also make their appearance and wage war upon their old enemies. This is one reason why in the older settled parts of the globe insect outbreaks are less frequent, though they are by no means unknown. The disturbed relationship between plants and animals has there become re-established. Moreover a more diversified farming is the rule in older countries, and insects there do not find such an abundance of food as in regions where their favorite food is grown upon a very large scale.

To enable the reader to recognize his friends and foes amongst insects the following two artificial classifications are given. Both are very simple, and the study of insects, in most cases, requires no magnifying glasses. It is best to compare with both classifications any insect to be located, that no errors be made. Both classifications apply only to the adult or winged insects.

I.

Insects with both a biting and sucking mouth:
- Wings with few veins: *Hymenoptera.*

Insects with a biting mouth:
- Upper wings horny: *Coleoptera.*
- Upper wings like pergament: *Orthoptera.*
- Upper wings with many veins: *Neuroptera.*

Insects with a sucking mouth:
- All wings scaly: *Lepidoptera.*
- Only two wings: *Diptera.*
- Upper wings halfleathery and halfmembranous: *Hemiptera.*

II.

1. With two wings: *Diptera.*
2. With four wings:
   - A. Upper and lower similar:
     - a. All wings scaly: *Lepidoptera.*
     - b. All wings naked or a little hairy:
       1. Wings with numerous veins: *Neuroptera.*
       2. Wings with few veins: *Hymenoptera.*
   - B. Upper and lower wings dissimilar:
     - a. Mouth-parts forming a sucking tube: *Hemiptera.*
     - b. Mouth-parts not forming a sucking tube:
       1. Upper wings horny: *Coleoptera.*
       2. Upper wings like pergament: *Orthoptera.*

INSECTS WITH COMPLETE METAMORPHOSIS.

HYMENOPTERA (membrane-wings.)

This order of insects seems to include the most numerous and perfect forms of insects, such as Bees, Wasps, Ants, Ichneumon-flies, Gall-flies, Saw-flies and Horntails. The order is distinguished by the possession of both a biting and sucking mouth and by having four similar wings with few veins. Most of the insects belonging to it undergo the most complete metamorphosis. Their larvæ are usually unable to search for food and have to be fed by the adults unless it is stored up for them in such a manner that they are surrounded by it. The saw-flies form an exception, however, and they live like the caterpillars of butterflies, in fact frequently resemble them so much as to be called "False caterpillars." Among the members of this order we have many that act very beneficially by fertilizing most of our flowers, by producing honey and wax, and by destroying injurious insects. Others are very destructive and hence are great enemies to farming.

Hymenoptera may be divided into two sections:

1. *Stinging species*, such as Bees, Wasps, Digger-wasps, Ants, etc.

2. *Piercing species*, such as Ichneumon-flies, Gall-flies, Saw-flies, Horn-tails.

1. The stinging hymenoptera are divided into four tribes: *Bees*, *True wasps*, *Wood-wasps*, *Sand and Digger-wasps*.

Bees are classed as *social*, *solitary* and *parasitic*. To the first belong the well-known Honey-bee and Bumble-bee;

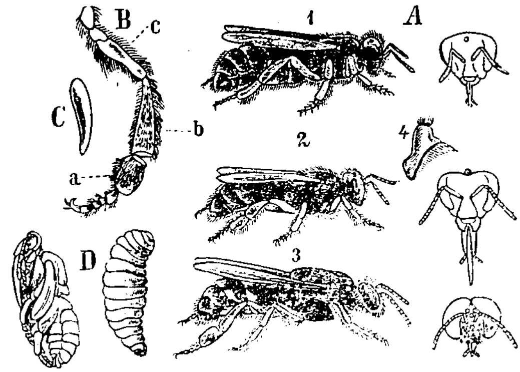

Fig. 8. A. 1, Queen bee: 2, Worker bee. 3, male; heads of same to the right. B. hind leg of worker, showing brush (a) and basket (b). C, egg enlarged. D, larva and pupa.

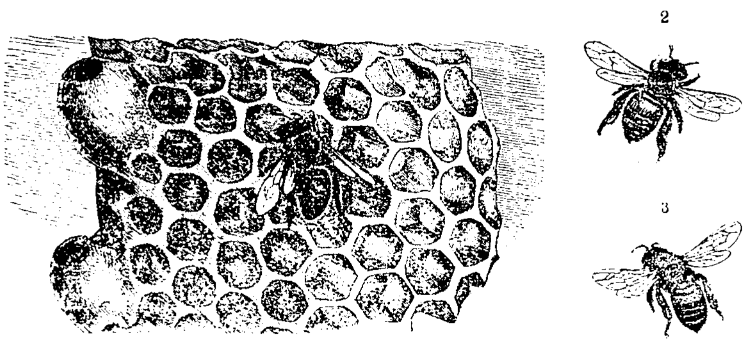

Fig. 9. 1, Honey comb with two queen-cells and German bee: 2, Italian; 3, Egyptian bee.

(Figs. 8 and 9); to the second the Carpenter, the Mason and the Leaf-cutting bees.

The *True wasps* and *Digger-wasps* have also social and solitary species. To the former belong the Paper-wasps, Hornets (Fig. 10, page 86), Yellow Jackets, and other well-known species. The Wood-wasps bore into wood, where they form their cells, and usually fill them with large numbers of plant-lice and other small insects. The Digger-wasps are our largest and brightest colored insects; the Mud-daubers (Fig. 11), Tarantula-killers and others belong here. The Ants (Fig. 12), of which we have a large number of species, close the section of stinging hymenoptera.

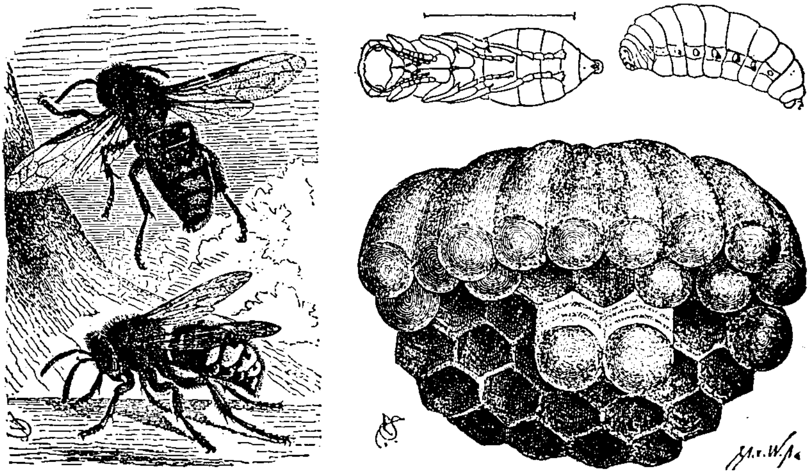

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Fig. 10. Hornets, their larva, pupa and cells.

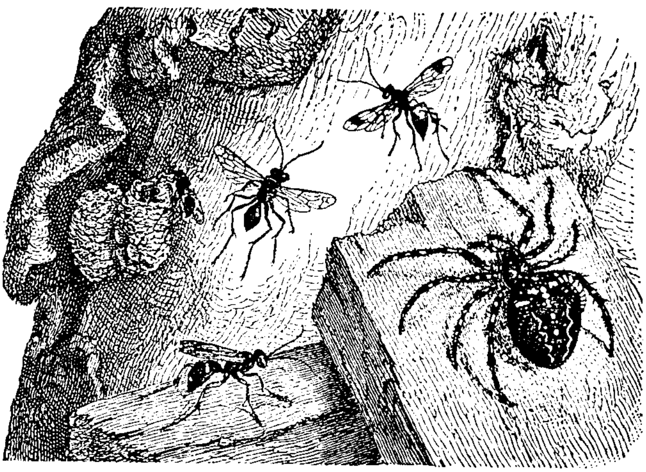

Fig. 11. Mud-dauber, and Pompilus with larva fastened to spider.

Fig. 12. Ant-hill. B, 1, male; 2, female; 3, worker, natural size.

Fig. 13. Parasite (*Ophion*) inserting egg in caterpillar.

2. The piercing species includes two very important groups of insects, the very useful *Insect-eaters*, and the destructive *Plant-eaters*.

Insect-eaters (Figs. 13, 14, 15 and 16) contain several families, best known by the name of Ichneumon-flies and Chalcid-flies. To this series we must add the Gall-flies (Fig. 17 and 18), well known by the peculiar swellings or galls they cause to form upon various plants.

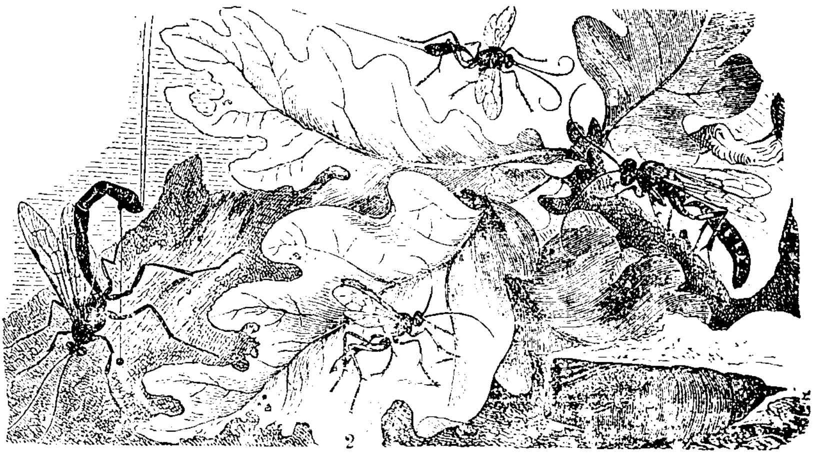

Fig. 14. Parasites. *Ichneumon* above pupa destroyed by it. *Ephialtes* in the act of laying eggs upon wood-boring larva.

Plant-eaters contain such insects as Horn-tails (Fig. 19), and Saw-flies (Figs. 20 and 21). The latter are the parents of the so-called "False Caterpillars" or slugs, so destructive to many species of wild and cultivated plants. The Horn-tails contain but few species, the larvæ of which inhabit the solid wood of trees.

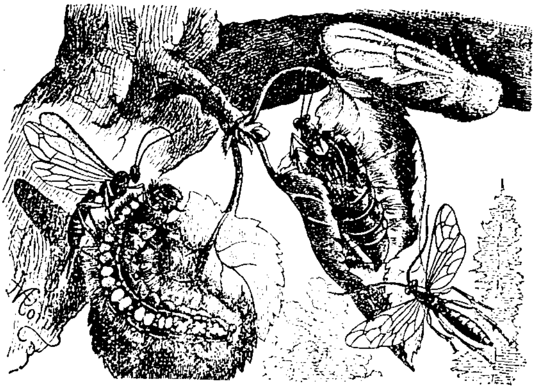

Fig. 15. Parasites. *Pimpla* female laying egg in caterpillar; another issuing from pupa of moth; below it a male, natural size.

Fig. 16. Parasite (*Microgaster*); its larva issuing from caterpillar.

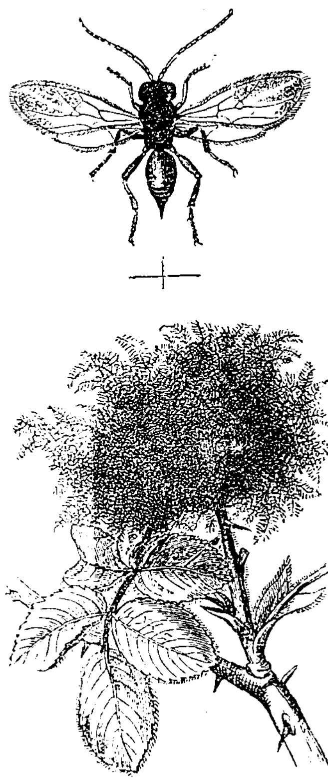

Fig. 18. Rose-gall and Gall-fly.

Fig. 17. Oak-galls and Gall-flies (1, 2 and 3).

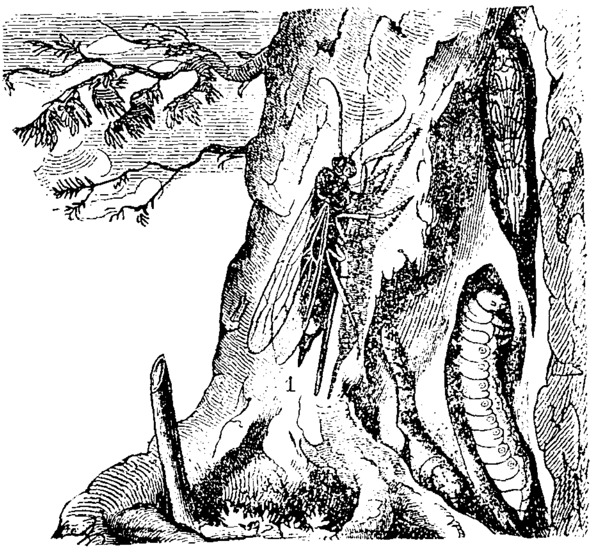

Fig. 19. Horn-tail, larva, pupa and adult.

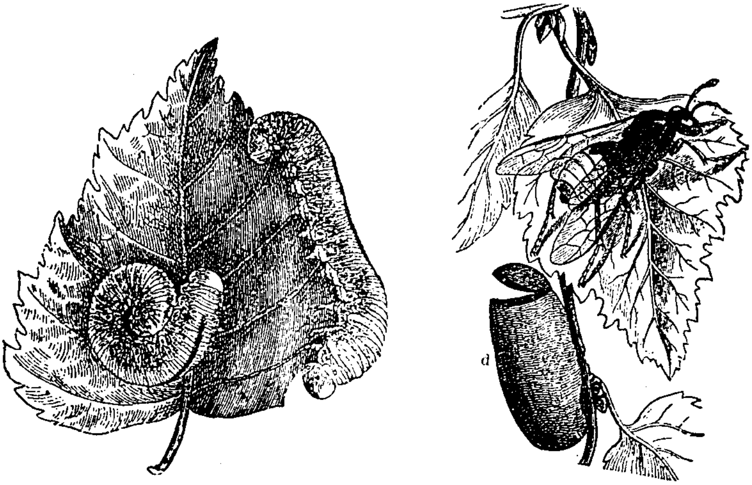

Fig. 20. Large Saw-fly, larvæ, cocoon (d) and adult insect, natural size.

Fig. 21. Saw-flies, natural size.

COLEOPTERA (sheath-wings.)

This order is usually considered the largest one, as more than one hundred thousand described beetles are already in our collections. Yet, with the exception of a very few extreme forms, all the species can be readily recognized by their sheath-like upper wings, which meet in a straight line down the back and cover not alone the abdomen but also the two lower joints of the thorax. These upper wings are not used for flight, but to protect the softer parts below. Only the lower and soft wings, possessing but few veins, and which are usually during rest folded beneath the upper ones, are used for flight. Beetles have a biting mouth and pass through a complete metamorphosis. Many beetles are very injurious, others are indifferent to farming, and still others are decidedly beneficial.

Beetles are divided into two divisions:

1. *True beetles*, with all mouth-parts present.

2. *Snout-beetles*, in which the front part of the head is prolonged into a beak or snout.

1. True beetles are usually divided according to the structure of their feet and their feelers.

Carnivorous beetles, with thread-like antennæ.

Here belong Tiger-beetles (Fig. 22), Ground-beetles (Fig. 23), Carnivorous Water-beetles (Fig. 24), Whirligigs or Apple-smellers. Almost all are beneficial.

Fig. 22. Tiger-beetles, with larva and pupa. Slightly enlarged.

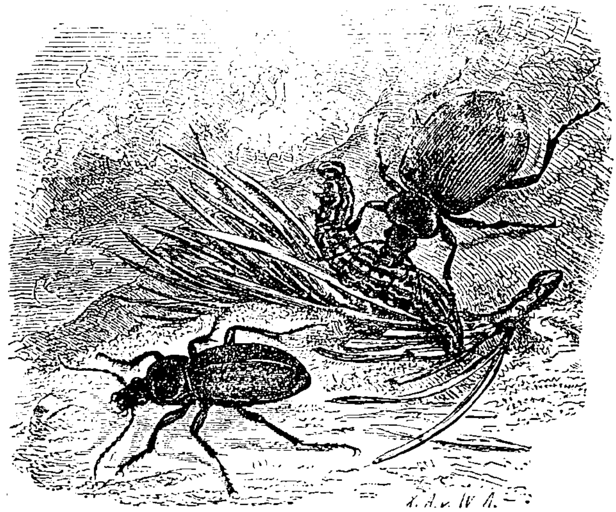

Fig. 23. Ground-beetles.

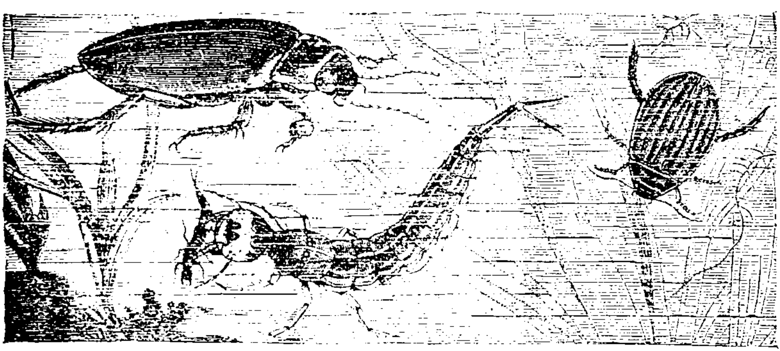

Fig. 24. Carnivorous Water-beetles.

Club-horns, with club-shaped antennæ.

Here belong Burying-beetles, Rove-beetles, Lady-bugs (Fig. 25), Larder-beetle (Fig. 26), Carpet-beetles and others of various habits. Mostly beneficial, with exception of Larder-beetles and Carpet-beetles.

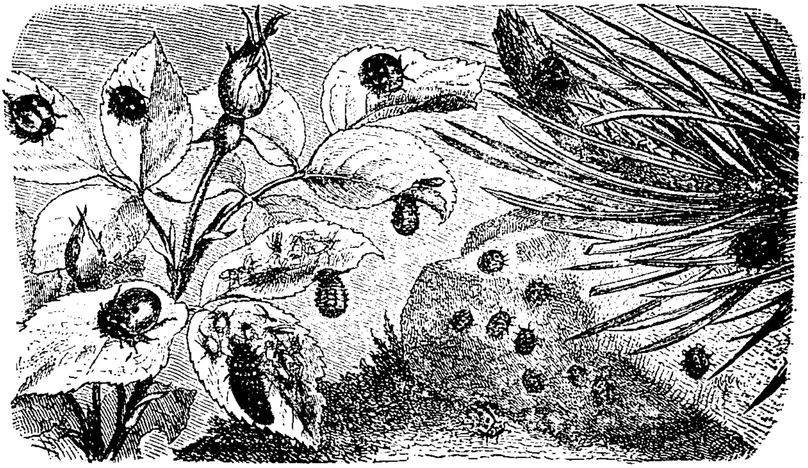

Fig. 25. Lady-bugs, with larva and pupa. Natural size.

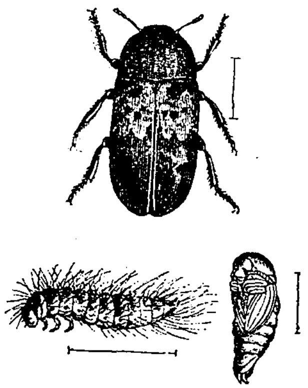

Fig. 26. Larder-beetle, with larva and pupa.

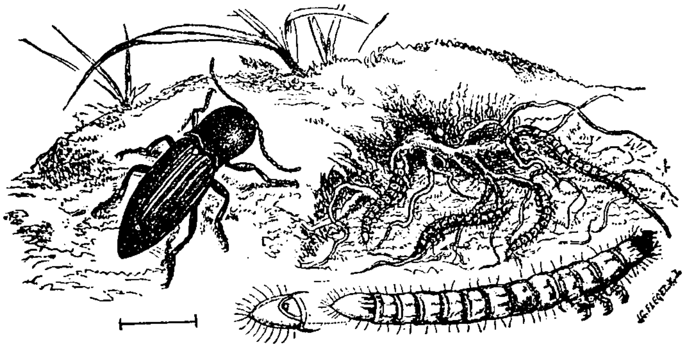

Fig. 27. Snapping-beetle or Wire-worm, with larvæ.

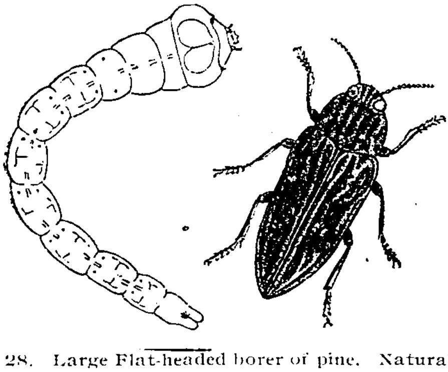

Fig. 28. Large Flat-headed borer of pine. Natural size.

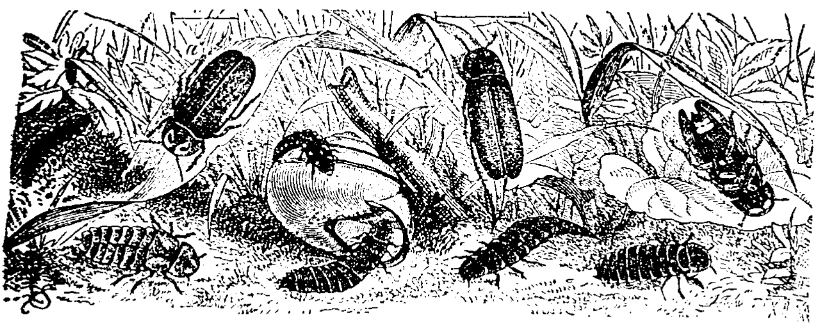

Fig. 29. Fire-flies and their larvæ.

Saw-horns, with toothed or serrated antennæ.

Wire-worms or Snapping-beetles (Fig. 27), Flat-headed borers (Fig. 28), Fire-flies (Fig. 29), Soldier-beetles (Fig. 30), etc., belong here. The first two are mostly injurious; the last two are beneficial.

Fig. 30. Soldier beetles.

Leaf-horns, with knobbed antennæ composed of many leaf-like parts.

Stag-beetes, Tumble-bugs (Fig. 31), Rose-beetles, May-beetles (Fig. 32), June-bugs, Rhinoceros-beetles, etc. All more or less injurious.

Plant-eaters with bead-like antennæ (True Leaf-beetles) or with very long horns (Round-headed Borers).

Among the former we have the smaller forms, as the Potato-beetle (Fig. 33), Poplar Leaf-beetle (Fig. 34), Cucumber beetle, Striped Squash-beetle, Flea-beetles (Fig. 35), and others like the Pea and Bean-weevils. Among the latter we have some very large insects. All beetles belonging here have very long and prominent horns, so that this series of plant-eaters is frequently called Longicorns (Fig. 36). The

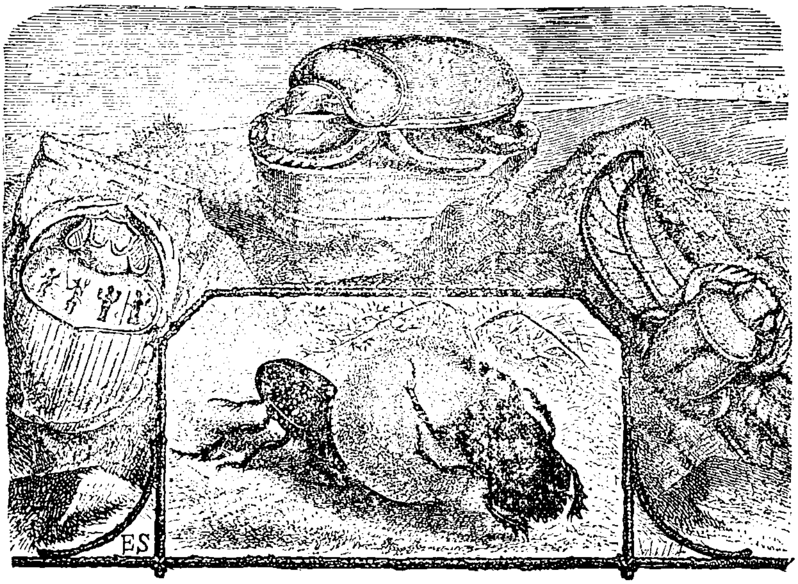

Fig. 31. Tumble-bug. Egyptian sculptures of the Sacred-beetle.

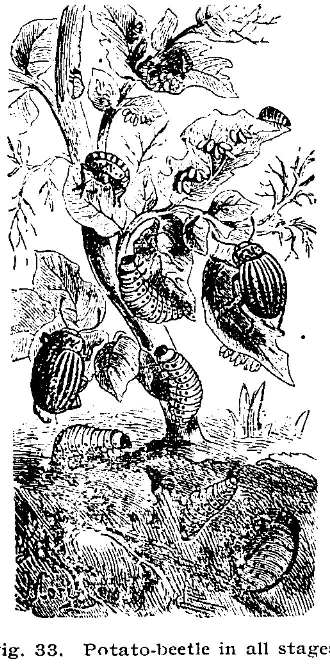

Fig. 33. Potato-beetle in all stages.

common Twig-girdler or Round-headed Apple-tree Borer represent their usual forms. All injurious.

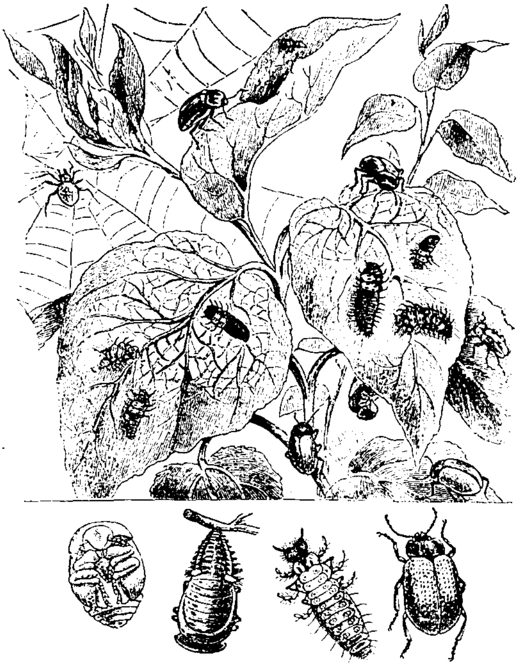

Fig. 34. Poplar Leaf-beetle in all stages.

Fig. 35. Different species of Flea-beetles and their larvæ.

Fig. 32. May-beetles at night.

Fig. 36. Destructive Longicorn. Their larvæ and work.

To the true beetles belong also the Blister-beetles (Fig. 37), Oil-beetles, Meal-beetles (Fig. 38), and some others, distinguished from the species mentioned before by having an unequal number of joints in their feet. Injurious and beneficial forms.

Fig. 37. Blister-beetles. With first larva.

2. Among the Snout-beetles we have insects like the Plum and Apple-curculios, Nut-weevils (Fig. 39), Rice and Corn-weevils, Bill-bugs, Plum-gouger and Bark-beetles (Fig. 40). All are injurious if infesting cultivated or useful plants.

Fig. 39. Nut-weevil.

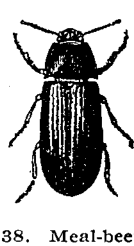

Fig. 38. Meal-beetle.

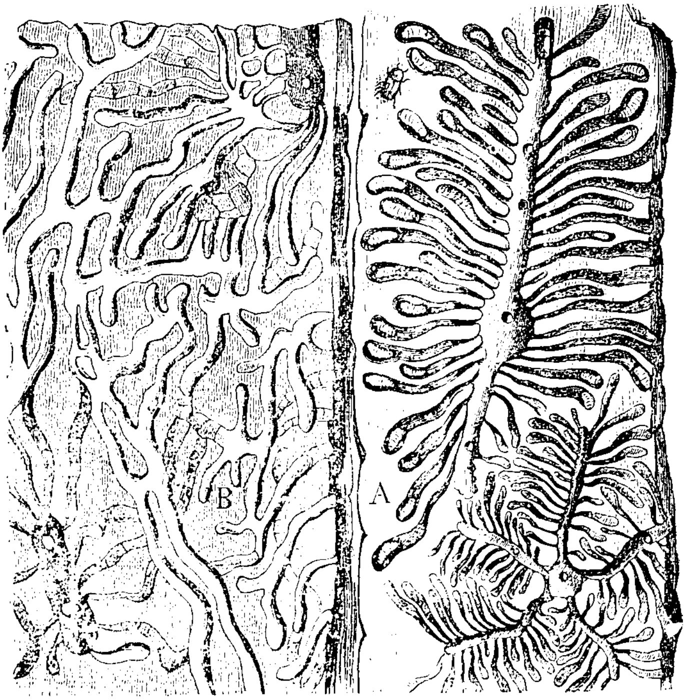

Fig. 40. Work of Bark-beetles.

LEPIDOPTERA (scale-wings).

Fig. 41. Currant-butterfly. Natural size.

Butterflies and moths are best known to the casual observer, the former being frequently so brightly colored as to be called "winged flowers." This order of insects is distinguished by having both sides of their wings covered with many-colored scales, arranged in definite patterns, like shingles upon a roof. Insects belonging here have in their perfect or winged stage the mouth-parts united in a long tongue coiled up like a watch spring. They undergo a perfect metamorphosis, and in their larval stage they are well known as caterpillars. In this stage they belong most decidedly to the biting insects, as it is in this stage that a large number of them become very destructive. With very few exceptions caterpillars feed upon leaves, fruit and wood, while many of the moths themselves eat nothing, or honey and other fluids.

Lepidoptera are usually divided into two divisions:

1. *Butterflies*, with club-horns.

2. *Moths*, with variable horns.

1. The butterflies are day flyers, and have stiff antennæ ending in a knob or club. Examples are the Parsley Swallow-tail, the White Cabbage-butterfly and Currant-butterfly (Fig. 41.)

2. The moths are divided into many families, such as Sphinx-moths, Clear-winged moths, Spinners, Owlet or Cut-worm moths, Span-worms or Measuring-worms, Snout-moths, Leaf-rollers, Tineids and Plume-moths.

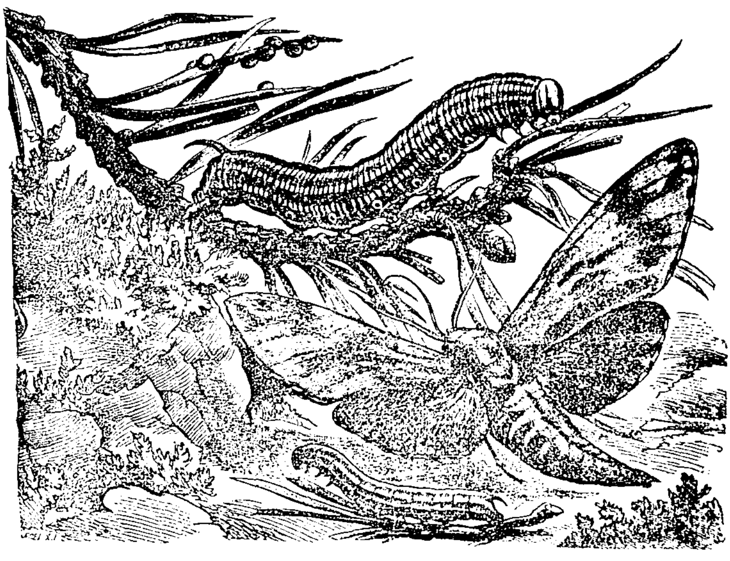

Fig. 42. Pine-sphinx. With eggs, young and old caterpillars.

Sphinx-moths are large and bulky insects which fly at dusk, and produce large caterpillars possessing usually a pointed horn on tail. The Ash-tree-sphinx and Pine-sphinx (Fig. 42), are examples of this family. Clear-winged moths are small and resemble more or less closely some wasp or fly.

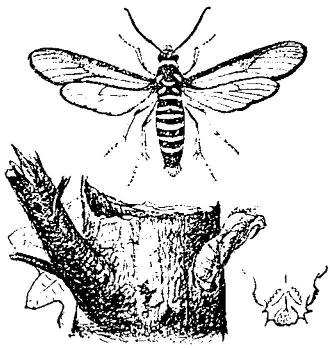

Fig. 43. Glassy-winged Oak-borer and empty pupal skin.

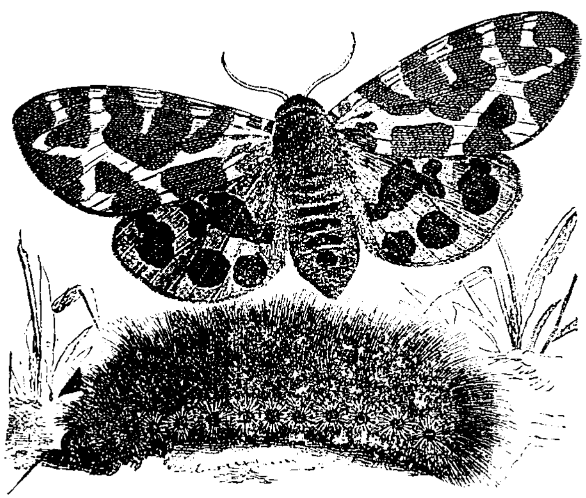

Fig. 44. Large Bear, with larva. Natural size.

Their larvæ are all very injurious borers, as for instance the Oak-borer (Fig. 43), and the Currant-borer. Spinners are bright-colored, medium-sized moths (Fig. 44), though some of our largest insects belong to this family, for instance our common native Silk-moths. Most of their caterpillars spin

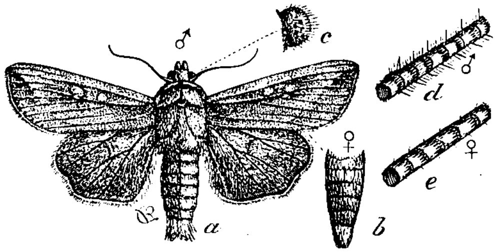

Fig. 45. Army-Worm. Caterpillar, pupa and adult.

Fig. 46. Geometer, with caterpillars and pupa.

silken cocoons, inside of which they transform to pupæ, as is the case with our destructive Tent-caterpillars. Owlet-moths or Cut-worm moths are night-flying, medium-sized insects, usually of very plain colors, though remarkable exceptions occur. Their caterpillars are more or less injurious, depending upon the value of the food they consume. The Army-worm (Fig. 45 and 45½), Lesser Army-worm, Onion Cut-worm, Corn-worm are familiar examples. Span-worm moths are slender insects, with large and weak soft-colored wings.

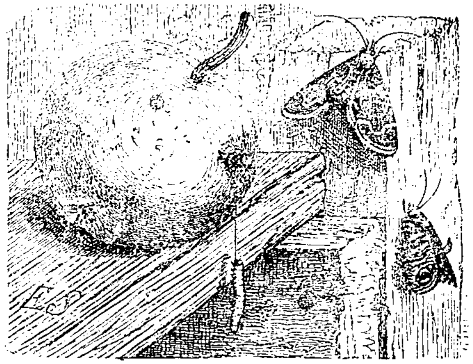

Fig. 47. Apple-worm and moth. Above Flour-moth.

Fig. 48. Grain-moth.

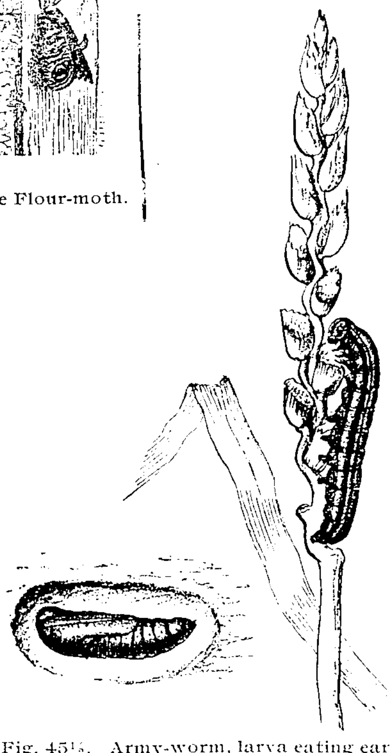

Fig. 45½. Army-worm, larva eating ear of wheat, and pupa.

They produce the peculiar "measuring worms" "or loopers" (Fig. 46), that frequently resemble very closely some dead twig. Some species, like the Canker-worms, have wingless females. The other families of lepidoptera are all small with various habits. Grass-worms, the Codling-moth, Flour-moth (Fig. 47), Grain-moth (Fig. 48) and Bee-moth (Fig. 49), Grape-vine Plume and allied forms are familiar examples.

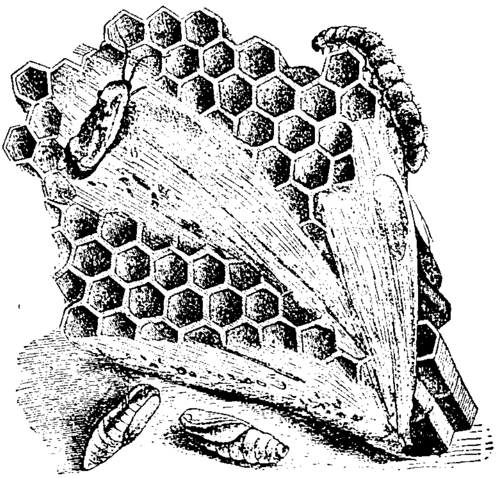

Fig. 49. Bee-moth. All stages.

DIPTERA (two-wings.)

All the members of this order, such as House-flies, Blow-flies, Bot-flies, Mosquitoes, Gnats, etc., are at once distinguished from all other insects by having only one pair of wings. The hind wings are rudimentary, usually thread-like, each ending in a little knob, which are called *halteres* or *poisers*. All flies are soft and usually rather small. The structure of their mouths varies greatly, but all are equipped for sucking fluids. Several species of flies can inflict painful injuries as their jaws are modified in such a way as to act like sharp lancets strong enough to pierce even the tough skins of large animals. The antennæ of flies are either very short, or long and sometimes feather-like. The metamorphosis of all flies is complete, yet there is a great difference among their pupæ, which are either enclosed in the hardened larval skin or resemble the free pupæ of Hymenoptera and Coleoptera. In some cases, as in the

Mosquito, the pupa is active, but does not consume any food. The larvæ of flies are generally called maggots.

Diptera are usually divided into two divisions:

1. Species in which the free pupa leaves the larval skin through a slit between the seventh and eighth joints.

2. Species in which the pupa is enclosed in the larval skin, from which the perfect insect escapes through a circular hole on top of the *puparium*.

To the first division belong flies like the Gall-gnats, Hessian-fly (Fig. 50), Wheat-midge, Buffalo-gnats, Mosquitos (Fig. 51), Crane-flies, Gad-flies (Fig. 52), Robber-flies, Bee-flies and parasitic Anthrax-flies (Fig. 53.)

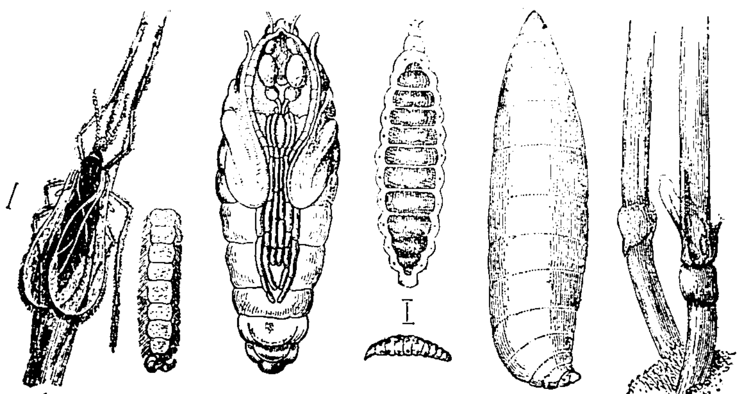

Fig. 50. Hessian Fly. 1. Adult female; 2. Male abdomen; 3. Pupa removed from "Flax-seed"; 4, 5, Larva; 7, "Flax-seed" in position.

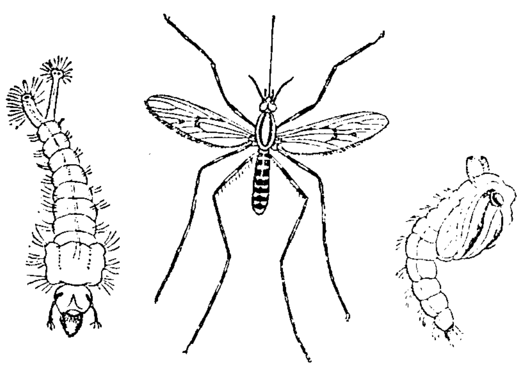

Fig. 51. Mosquito. With larva and pupa.

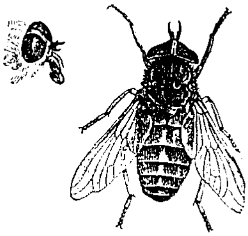

Fig. 52. Gad-fly or Horse-fly.

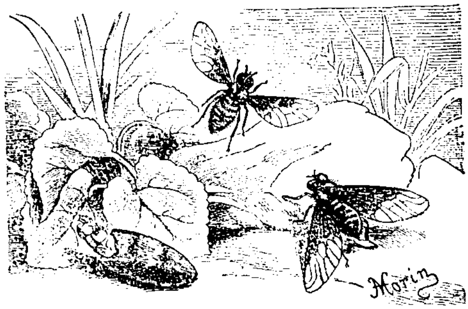

Fig. 53. Parasitic Anthrax-fly.

To the second division belong flies like the Syrphus-flies (Fig. 54), Bot-flies (Fig. 55), Tachina-flies, House and Flesh-flies (Fig. 56), Cheese-flies and Frit-flies (Fig. 57.)

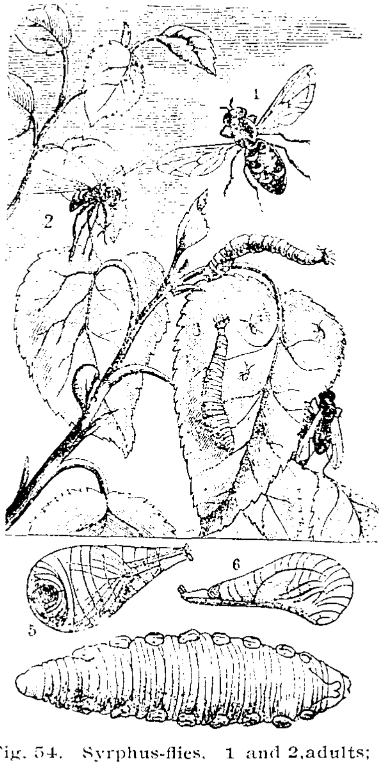

Fig. 54. Syrphus-flies. 1 and 2, adults; 3, larva eating lice; 4, contracted larva; 5 and 6, pupa.

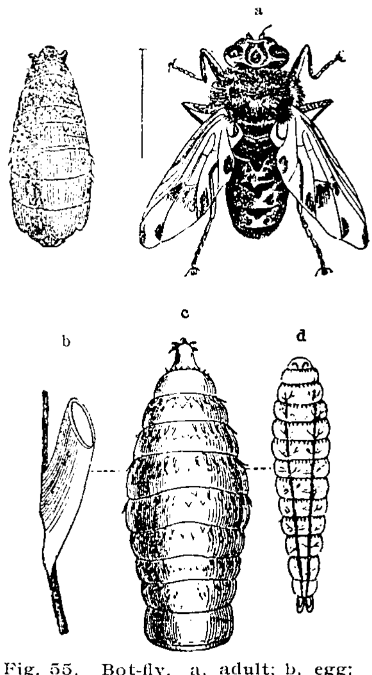

Fig. 55. Bot-fly. a, adult; b, egg; c, mature larva; d, young larva; e, puparium.

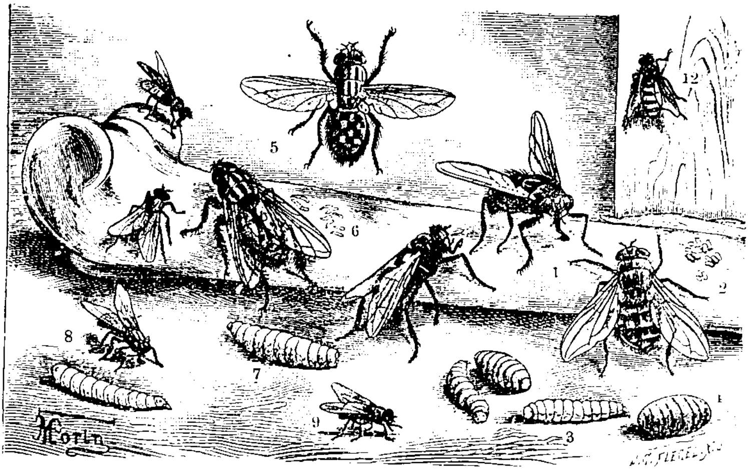

Fig. 56. Flesh and House-flies, with their eggs, larvæ and pupæ. 12. House-fly killed by fungus.

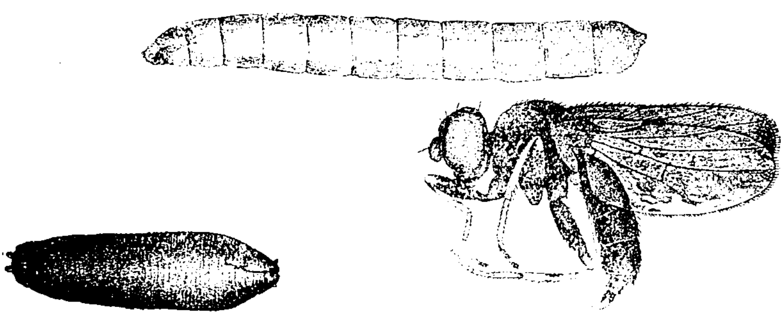

Fig. 57. Frit-fly. Larva, pupa and adult.

As a general rule all flies are considered very injurious insects, but there are many very pleasing exceptions. Tachina-flies, for instance, are our best friends, checking the undue increase of noxious insects. Without Syrphus-flies the Leaf-lice would soon destroy all vegetation. Even the trouble-some House-fly must be called beneficial, since it performs the functions of a public health-officer, and performs it well. Without it the smaller particles of decaying animal and vegetal matter would soon fill the air near our houses with fatal odors.

Among the flies of lower organization may be counted the Fleas (Fig. 58), which in their early stages possess the

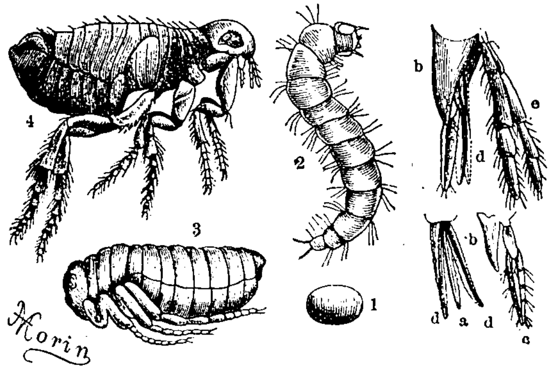

Fig. 58. Common Flea. 1, egg; 2, larva; 3, pupa; 4, adult Flea; a-e, mouth-parts.

characters of the order. The peculiar Sheep-tick and Horse-tick are also degraded flies—degraded in form as a result of leading a parasitic life.

INSECTS WITH AN INCOMPLETE METAMORPHOSIS.

HEMIPTERA (half-wings).

Insects belonging to this order are *bugs*, a term that should not be applied to any other order of insects. Many members of this order possess wings which are half-membranous and half-leathery, whence the compound Greek term *hemi-ptera*—half-wings. All obtain their food by sucking the juice of living plants or animals. To enable them to do so the mouth is composed of a three or four-jointed beak, in which are snugly hidden two pairs of fine bristles well adapted to pierce and to suck. The metamorphosis of bugs is incomplete, and their pupæ are as active and feed as well as the larvæ or the adults. We may arrange all hemiptera into three groups:

1. *True Bugs* (*Heteroptera*).
2. *Harvest-flies, Leaf-hoppers, Plant-lice* (*Homoptera*.)
3. *Lice*.

The True Bugs are the only ones that are distinguished by half-wings, and to which the definition of bugs given above applies in every particular. They are *terrestrial, amphibious* or *aquatic* in their habits. The terrestrial bugs are either *plant-feeders* or *cannibals*. The former (Fig. 59 and Fig. 60—1 and 2), mostly very injurious insects, have a more slender beak than the latter. Familiar examples are the

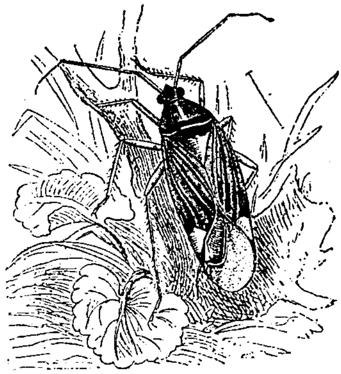

Fig. 59. Plant-feeding Heteroptera (*Calocoris.*)

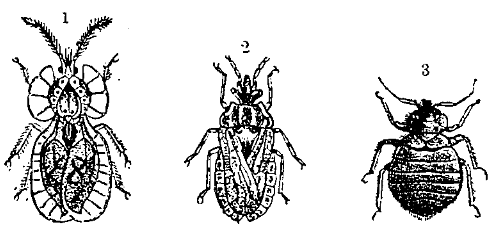

Fig. 60. Plant-feeding Heteroptera: 1, *Tingis*; 2, *Aradus*. Cannibal Heteroptera: 3, Bed-bug.

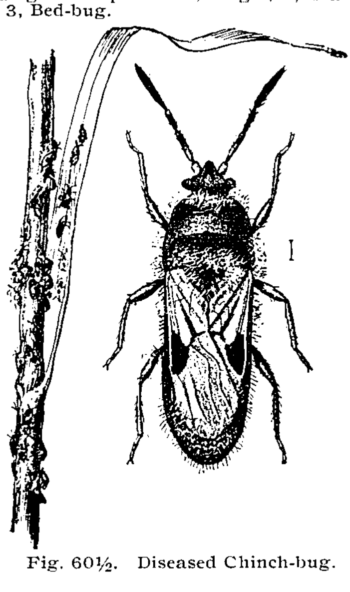

Fig. 60½. Diseased Chinch-bug.

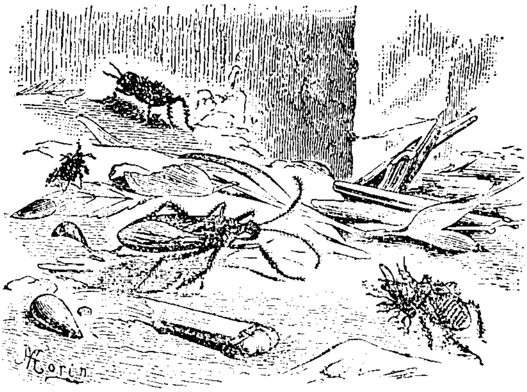

Fig. 61. Blood-Sucker (*Reduvius*) with active larvæ and pupæ.

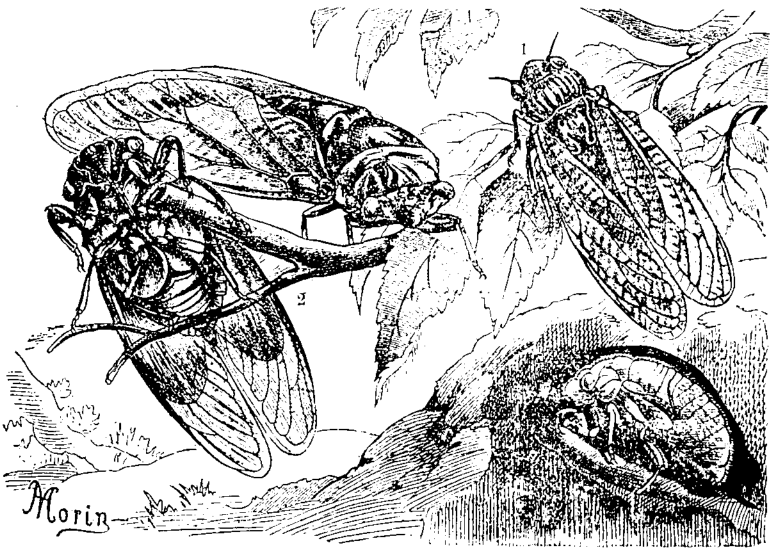

Fig. 62. Harvest-flies: 1, *Cicada orni*, common in Manna in drug stores; 2, Singing Cicada, with pupa.

Squash-bug, Chinch-bug (Fig. 60½), Tarnished Plant-bug, Four-lined Leaf-bug, Negro-bug. Among the cannibal bugs, with shorter and stouter beaks we have many friends, but also some dreaded foes. Insects like the Soldier-bug, Blood-sucker (Fig. 61) and Bed-bug (Fig. 60-3) belong here.

Among the amphibious bugs the best known are those that run like spiders over the surface of water in pools and ponds. The Giant water-bug or the Electric Light-bug, the Water-scorpion and the Boat-man are familiar forms of aquatic bugs.

2. The second group of bugs, the *Homoptera*, are distinguished by having their wings of the same texture throughout. This group is divided into many families, all of which are vegetable feeders. Familiar examples of the families are the Harvest or Dog-day flies (Fig. 62), insects distinguished from most others by the possession of a sound-producing organ, to which belongs the famed Seventeen-year Cicada or Locust; the Tree-hoppers, as the Buffalo Tree-hopper; the Leaf-hoppers, as the Grape-vine Leaf-hopper and the Spittle-insect (Fig. 63). The Plant-lice (Fig. 63½) also belong

Fig. 63. Spittle-insect. With "Cuckoo spittle" produced by larvæ and pupæ.

here, many of which are exceedingly injurious. As already mentioned these insects reproduce in two ways—by laying eggs and by producing living offsprings. The Bark-lice or Scale-insects are also members of this group. Although generally very injurious some form a notable exception, as the Cochineal insect (Fig. 64), that produces the beautiful crimson color; others produce wax and lac.

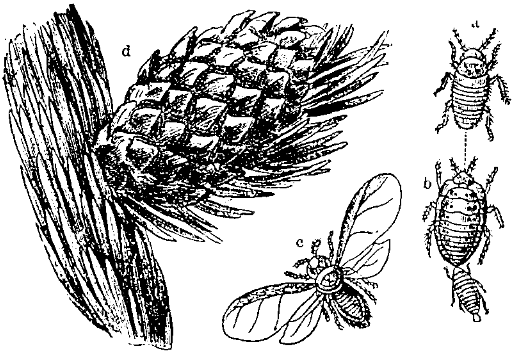

Fig. 63½. Pine-louse; *a*, young louse; *b*, female producing young; *c*, winged louse; *d*, gall produced by lice.

Fig. 64. Cochineal insect.

3. Lice (Fig. 65) are also members of the order of hemiptera, and members not in good standing. They are all small, wingless, and are parasitic upon mammals, including man. Bird-lice, though very similar to true lice, do not belong here, as they possess a biting, not a sucking mouth.

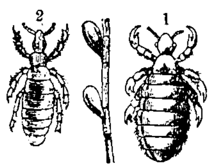

Fig. 65. 1, Head-louse with eggs; 2, Body-louse.

ORTHOPTERA (straight-wings).

Grasshoppers, locusts, katydids, crickets, walking-sticks, roaches and others are members of this order. All are fairly large, possess a biting mouth and pass through an incomplete metamorphosis. Some of the most injurious insects belong to this order, such as the Migratory locusts, too well known in Minnesota.

We can divide this order into four groups according to the structure of their legs and their mode of locomotion: *Jumpers*, *Walkers*, *Graspers* and *Runners*.

1. Among the *jumpers* we place such insects as locusts, grasshoppers and crickets. Locusts (Fig. 66 and 67), fre-

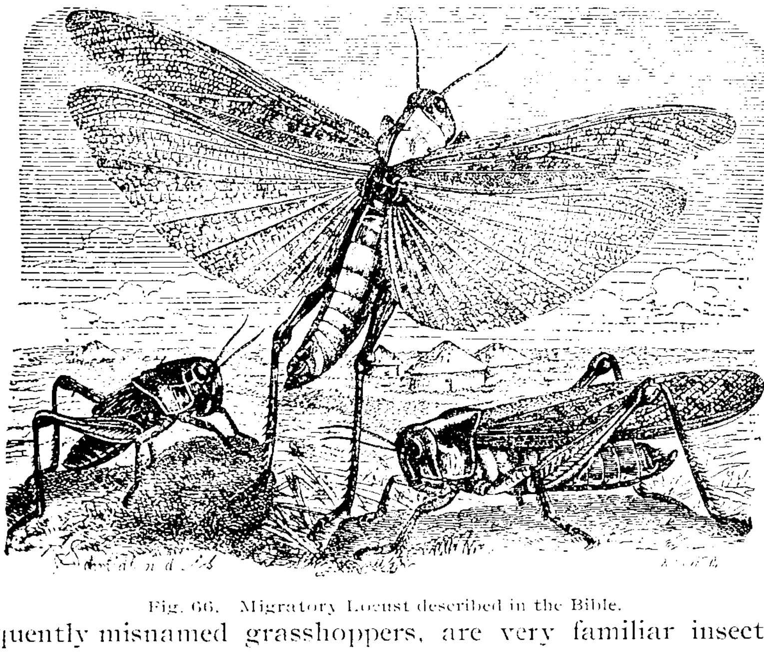

Fig. 66. Migratory Locust described in the Bible.

quently misnamed grasshoppers, are very familiar insects which devour all sorts of grass or grains and other low plants. As a general rule they are of a dingy color so as to resemble the ground upon which they live, though a few have bright-colored underwings. These are, however, only displayed when the insect is on the wing and then only for a very short time, since the common locusts do not readily fly except when disturbed or during their mating season. A few

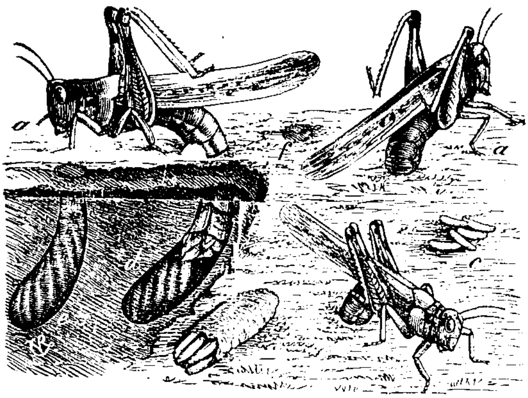

Fig. 67. Rocky-Mountain Locust, in the act of laying eggs.

are social and migrate together in such numbers as to resemble clouds (Fig. 68). Their eggs are deposited in the ground in bean-shaped masses. The males of most jumpers produce a loud sound by fiddling, or by rubbing the inner surface of the hind thighs over the mid-rib of the upper wings.

Among the *grasshoppers* we have such familiar insects as the Katydids, Cone-heads and Sword-bearers. Most of them are bright green, more or less arboreal, and produce their love songs by rubbing or grating together the base of their upper wings, which are modified for this purpose. The eggs of these insects are usually inserted into the pith of plants or glued upon the surface of twigs.

Crickets, also members of the jumping orthoptera, can be separated into three groups, viz: Tree-crickets, Field-crickets and Mole-crickets. Among the first group we have the injurious Snowy-cricket; among the second the big-headed black Field-crickets (Fig. 69½), which are a very familiar sight near stone walls. The Mole-cricket (Fig. 69) is not often seen, as it seldom leaves its peculiar burrow underground, and if so only at night. Not on account of its burrowing habits alone has this insect received the name of Mole-cricket, but also because its first pair of legs are transformed into digging implements like those of a mole. Though all crickets are more or less injurious they are not without their redeeming characters, since they eat large numbers of injurious insects.

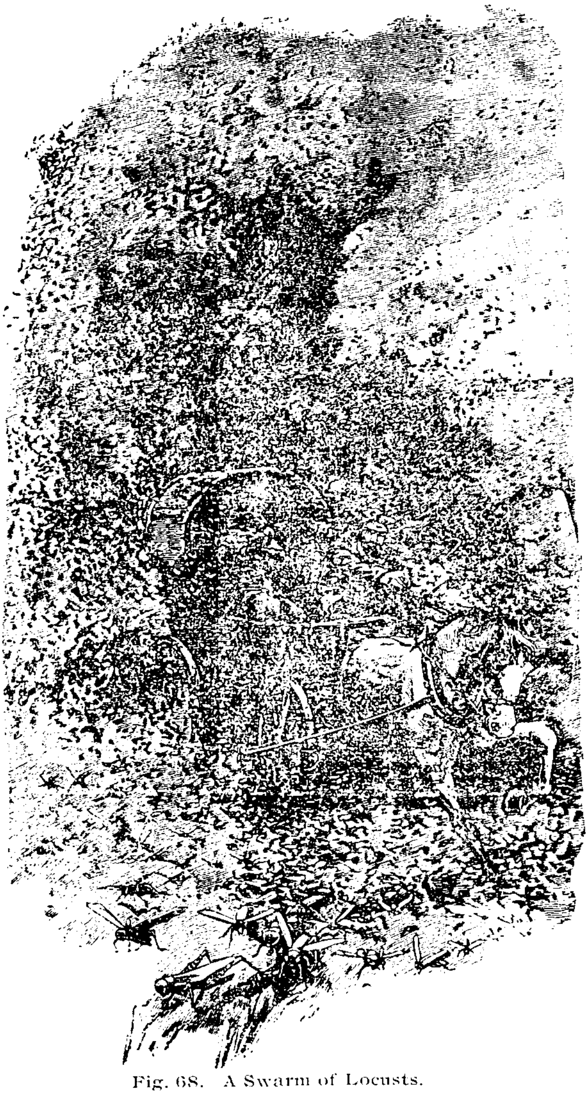

Fig. 68. A Swarm of Locusts.

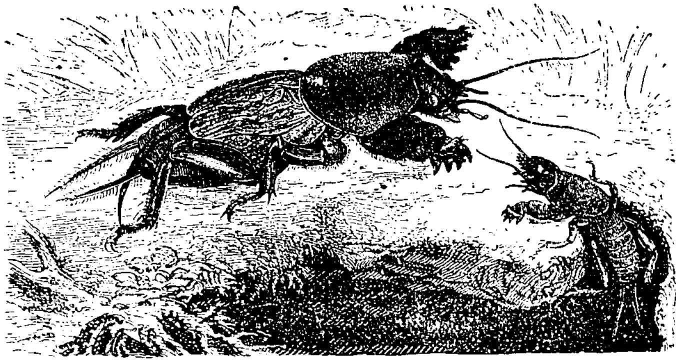

Fig. 69. Mole-cricket.

They also produce a sound in a manner similar to the grass-hoppers.

It should be mentioned here that the sounds produced by insects are made only by the males to call the females.

Fig. 69½. Field-cricket. 1 and 2, adults; 4, active pupa. Below 1 crickets just hatched.

2. *Walkers.* "Walking-sticks," "Walking-leaves," etc. are very peculiar insects, and well deserve the above names. We have but one species in Minnesota, which looks—when at rest—exactly like a dry twig (Fig. 70). When moving it seems to be suffering from some acute pains in the joints. Every external organ of these insects is drawn out as long as possible, which may account for the apparent pains. The insect feeds upon all kinds of foliage, and is sometimes de-

structive to our hazelnuts. It drops its peculiar eggs singly and is not in the mood to produce love songs.

3. *Graspers*, or "Devil's Riding Horses," "Camel-crickets" (Fig. 71), "Rear Horses," etc., do not occur in our state. They

Fig. 70. European Walking-stick with larvæ.

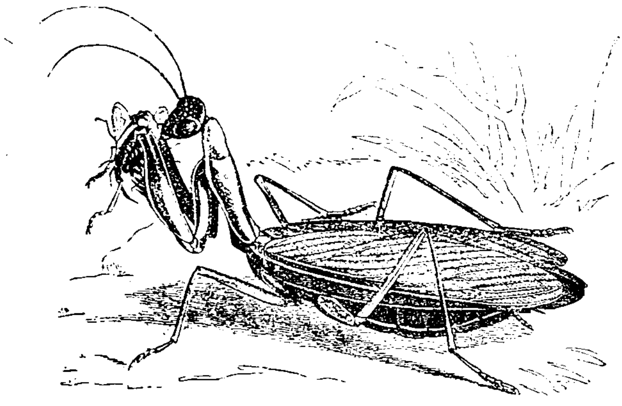

Fig. 71. Preying Mantis.

are quite common farther south, and are distinguished by their spiny front legs, well adapted to grasp their food, which consists of all kinds of insects. Their position during an apparent rest is that of praying, but woe to the poor unsuspecting victim that may come too near, as it will soon discover the fact that in this case praying is spelt preying.

4. *Runners* are represented by such insects as Cock-

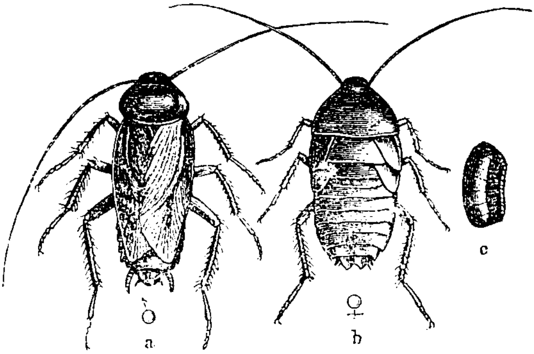

Fig. 72. Cockroaches: *a*, winged male; *b*, unwinged female, *c*, egg-mass.

roaches (Fig. 72), some of which are household pests, though the great majority of these disgusting insects live under loose bark of trees. They are all nocturnal in their habits and excel in the rapidity of their movements. Such injurious insects as the Croton-bug are familiar examples of these running orthoptera. They deposit their eggs in one yellowish-brown bean-shaped mass, which is frequently carried about for some time before being dropped into some crack or crevice.

The *Ear-wigs* also, a small group of insects distinguished by a formidable looking pair of forceps at their posterior end, belong to the orthoptera, and are illustrated in Fig. 73.

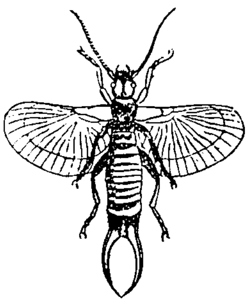

Fig. 73. Ear-wig.

The peculiar group of insects termed *Thrips* (Fig. 74) and the unwinged *Spring-tails* may also be arranged with the orthoptera. The former are more or less injurious, and occur frequently in vast numbers in the heads of wheat and clover. Spring-tails well deserve their popular name on account of their mode of locomotion. The so-called Snow-fleas (Fig. 75), which sometimes blacken the surface of the snow by their presence, are well known examples. The biting lice infesting animals, and chiefly birds, may also find a place at the end of orthoptera.

Fig. 74. Thrips, the dots upon wheat-plant showing natural size.

Fig. 75. Snow-fleas.

INSECTS WITH A COMPLETE OR AN INCOMPLETE METAMORPHOSIS.

NEUROPTERA (nerve-wings).

This is an order of insects that is now separated into many smaller ones, and for very good reasons; but as only a very few of the insects that form this assemblage are of any economic importance it is best to retain them all in this one order. All the insects that belong to it are distinguished by possessing wings with many veins and all have a biting mouth. The metamorphosis of the various families is quite different, in some cases it being a complete and in others an incomplete one. We divide them most naturally into two sections:

1. *With a complete metamorphosis* (*Neuroptera*).
2. *With an incomplete metamorphosis* (*Pseudo-neuroptera*.)

To the first section belong such insects as the Caddice-flies, Ant-lions, Lace-wings, Hellgrammite-flies and others.

In the sesond one we place Dragon-flies, May-flies, Stone-flies and White Ants. Some unwinged insects, as Book-lice may also find here a place.

Caddice-flies are aquatic in their early stages and feed upon small water animals. The larva always protects itself by a little house made of silk and covered in a more or less regular manner with all sorts of material found at hand. The mature insects look somewhat like moths denuded of scales (Fig. 76).

Ant-lions (Fig. 77) may possibly be found in Minnesota, but none have as yet been recorded. The adult insects have large lace-like wings and antennæ. Their larvæ dig peculiar pits in sandy soil and devour insects that fall into these traps.

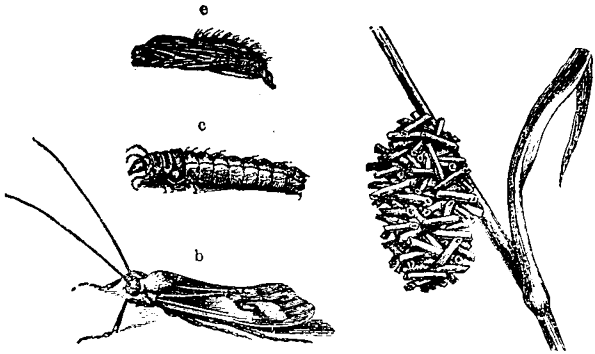

Fig. 76. Caddice-fly: *a*, house made of stems; *b*, adult; *c*, larva removed from house; *e*, pupa.

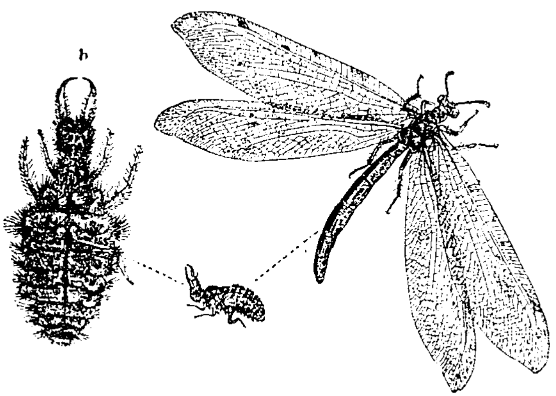

Fig. 77. Ant-lion, with larvæ, enlarged and natural size.

Lace-wings or Aphis-lions (Fig. 78) are very beneficial insects of small size. The mature and winged insects are usually green or pale red, and possess unusually prominent eyes of a golden color. The larvæ are flat, with very large jaws, and are almost constantly engaged in devouring their usual food, the plant-lice. Their round and white silken cocoon is very small in comparison with the large imago that issues from it through a circular lid. The eggs are fastened singly to a slender silken stalk, of which many are fastened side by side.

Hellgrammite-flies are large insects with a very forbidding aspect. The larva is aquatic and carnivorous. To them belong the dark colored and much smaller insects that

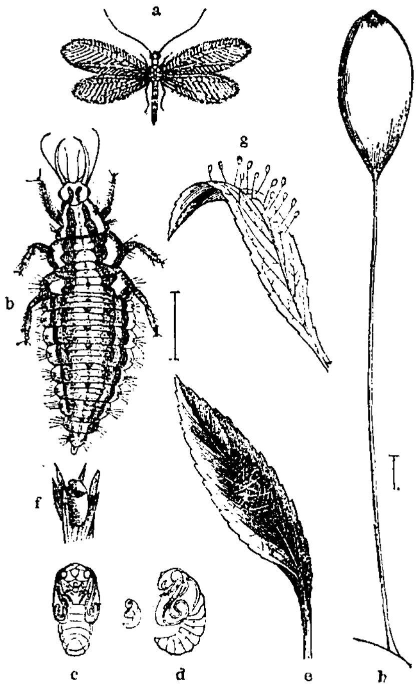

Fig. 78. Lace-wings: *a*, adult, natural size; *b*, larva, greatly enlarged; *c* and *d*, pupa; *f*, cocoon; *g*, eggs; *h*, egg, greatly enlarged.

are sometimes so numerous about the shores of our lakes (Fig. 79).

To the second section belong a number of our friends, such as the *Dragon-flies* or *Mosquito-hawks* (Fig. 80).

These active insects, almost constantly upon their wings during fine weather, possess four large wings of rather uniform size, frequently ornamented with bright spots and metallic colors. Their food consists of all sorts of adult insects, the smaller ones of which they eat without interrupting their flight. Immense numbers of mosquitos and gnats are destroyed by them, and as both mosquito-hawks and mosquitos are raised in the same pool of water the former never lack sufficient material for their enormous appetites. But as the pupa is as active in the water as the larva, constantly waging war upon other insects, they are really very beneficial in all three stages. In the early stages these dragon-

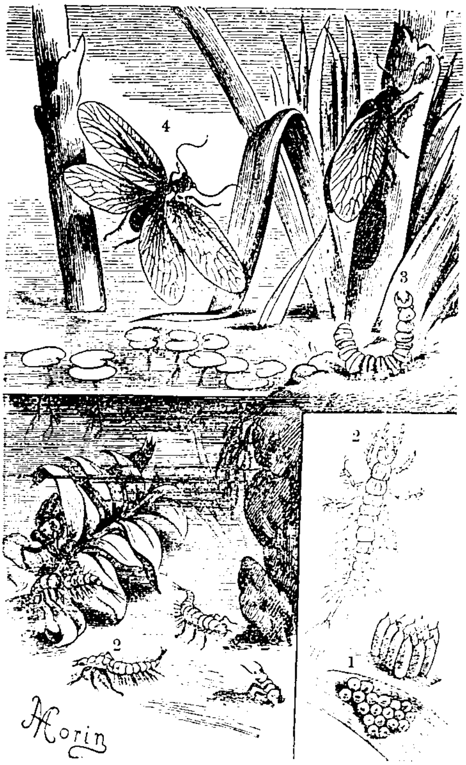

Fig. 79. Sialis: 1, eggs; 2: larvæ; 3, pupa; 4, adult flying, and depositing eggs.

flies posess a sort of mask, the anterior edge of which is provided with two sharp hooks. This whole mask can be greatly extended so as to reach a victim at a distance and carry it to the true jaws for mastication.

May-flies or "One-day flies" (Fig. 81) are exceedingly abundant upon some of our lakes, flying often in clouds over the shores and soon covering them with their dead bodies, which in some countries are gathered by the farmers as fertilizers. Lacking mouth-organs the few hours of winged existence are simply utilized by the insects to mate and to deposit their eggs. Their larvæ, which are aquatic, grow but slowly and have to pass many moults before reaching the adult stage.

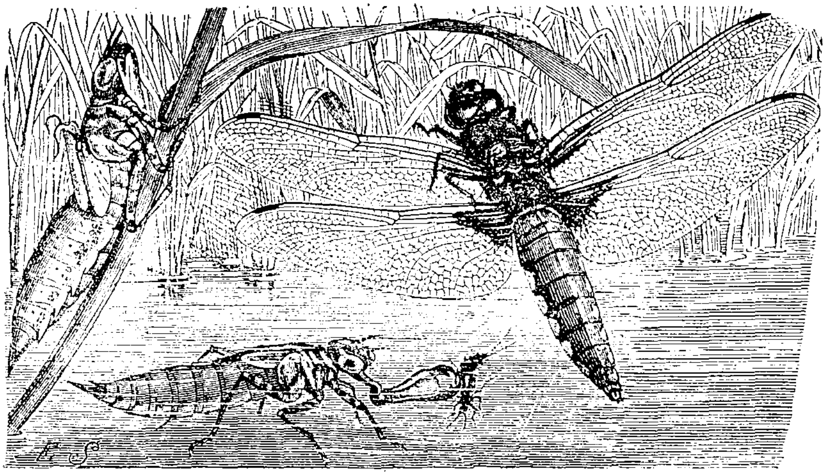

Fig. 80. Dragon-fly, with active pupa and empty pupal skin.

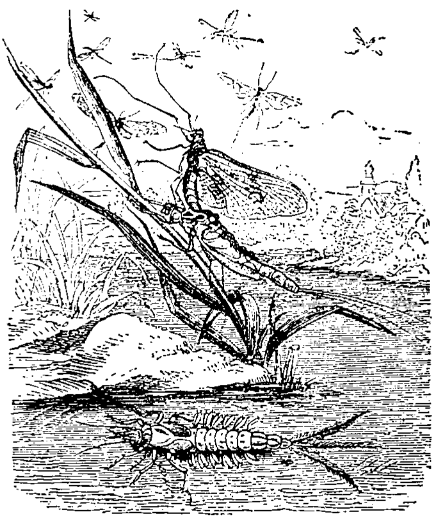

Fig. 81. May-fly (*Ephemera*) leaving shell, and active pupa

White-ants are not found in Minnesota; they are a feature of southern regions where they form large colonies like our true ants, in which we find, besides the males and females, workers and soldiers also. All white ants feed upon dead wood and are therefore useful scavengers in a state of nature.

ENTOMOLOGY, or the science of insects, is divided into several distinct branches. Some students devote their time to describing and classifying insects, and consider mainly their structures, not their habits or life-histories. Of course structure indicates to some extent habit. This strictly *scientific entomology* is very important, since without it entomology would simply be chaos. But scientific entomology is of very little use to the tiller of the soil, as it gives him only the scientific names of his enemies but not the means to protect himself against their depredations.

Economic, applied or practical entomology does not discard scientific entomology, without which it could not exist, but it centers its attention upon the habits of insects, so as to become enabled to devise the proper means either to combat or to protect them. Again there are persons who simply collect insects for the sake of having fine and complete collections. If this was their only aim they might as well simply gather a complete collection of old shoes, so far as their aid to entomology is concerned. But happily there are few of such collectors who simply collect bright insects and arrange them, perhaps, in a more or less spread-eagle style, or form out of bright colored carion-beetles the initials of a dearly beloved one. As a very general rule they discover many new species and permit the scientific entomologist to make good use of their diligence by giving him free access to their treasures.

Economic entomology is a very important science and becomes so more and more with increased knowlege. Prof. Fletcher, the Dominion Entomologist of Canada, in his Inaugural address, delivered before the third annual meeting of the Association of Economic Entomologists held at Washington, D. C., made the following remarks which will be a surprise to many readers, yet which are based upon very conservative estimates: "The amount of damage done to crops each year is so vast that the figures exite incredulity from those who do not study crop statistics. The agricultural products of the United States are estimated at about $3,800,000,000. Of this it is thought that about one-tenth is lost by the ravages of insects. This is in many cases unnecessary. In short a sum of $380,000,000 is given up without a murmur and almost without a struggle by the people of the United States." It would be folly to claim that all of this vast sum could be saved by applying all the means we possees to prevent this loss. But by studying closely the habits of injurious insects, and applying the remedies suggested by such studies at least one-fourth if not one-half of this fearful annual loss could be saved.

Economic entomology teaches two quite distinct methods to combat noxious insects, or in other words it teaches *natural* and *artificial* methods for this purpose. The former are based entirely upon the habits of insects, the latter upon their structure; upon the character of their mouth, whether biting or sucking, and upon the character of the skin, whether soft and easily affected by some chemical substance or hard and tough so as to resist it. Artificial means can be used, such as poison to enter the mouth or skin, or such as none-poisonous substances to cause death in various ways. Both methods can only be applied successfully when the habits and structure of the insects to be combatted are thoroughly known. As a very general rule natural remedies are to be preferred as they are more in harmony with nature, and not so apt, if properly applied, to kill the beneficial insects with the noxious ones.

NATURAL METHODS.

In many cases it is possible to capture some species of insects before they have caused much damage, and if this can be done at the right time it will not require much labor to check future damages.

CATCHING INSECTS BY NETS, BY JARRING AND BY BEATING.

Examples:—The few white Cabbage-butterflies that succeed in passing our winters safely and which appear on the wing in spring near the young cabbage plants can be readily caught by small boys and girls with a butterfly net, which anybody can easily make. By preventing these early butterflies from laying eggs none of the later brood can appear.

The different species of snout-beetles that infest our plum trees hibernate as perfect insects and visit the trees long before any leaves are found upon them.

By jarring the trees early in the morning these insects can be collected upon a sheet of muslin spread under the tree and killed.

By beating the young potato vines the beetles that have collected there to eat and to lay eggs can be gathered into a tin pail containing water with a little kerosene oil, and can thus be destroyed.

CATCHING INSECTS BY TRAPPING AND SEMBLING.

Examples:—Many of the caterpillars of the Codling-moth descend the apple trees to pupate. If a band of folded papers be put around the trunk they will go below this band, where they can readily be crushed.

The males of many destructive moths can be collected and killed by confining a freshly issued female under a sieve. Many males will be attracted to the female and will try to reach her, and while thus engaged can be captured. This method is often very effective, especially with our larger destructive moths.

CATCHING INSECTS BY ATTRACTING THEM TO LIGHT AND BAITS.

Examples:—A large number of injurious insects are attracted to strong lights, as may be seen in cities illuminated with electric lamps. By arranging a vessel with water, upon which floats some kerosene oil, under brightly burning lamps arranged in fields to be protected many destructive insects can be caught and killed.

By using lights many beneficial insects are also captured, most of which might be saved by using water alone.

Baits, consisting of various materials corresponding to the insects intended to be caught, are very attractive to certain kinds. Sugar or molasses dissolved in water and mixed with a little real vinegar attracts the moths producing cut-worms.

COLLECTING EGGS OF NOXIOUS INSECTS.

In many cases injurious insects can be greatly reduced in number by gathering and destroying their eggs at the proper time.

Examples:—The eggs of Cabbage-butterflies and Potato-beetles can be readily detected upon the young food plants. Eggs of the Tent-caterpillars are prominent during the winter upon the trees that are preferred as food, where they should be collected and burned. The eggs of the Migratory Locusts can sometimes be collected more readily and in larger numbers than the active insect itself.

BURNING DEAD TWIGS IN AND AROUND ORCHARDS.

Example:—The Currant-borers and similar insects remain in the dead or dying canes until mature. By burning canes thus infected in early spring the culprits are killed. The New York-weevil, destructive to plum trees, breeds in oaks, chiefly in those twigs that drop very readily. By gathering and burning these at the proper time the insects are prevented from invading orchards.

BURNING DEAD FOLIAGE, ETC.

Example:—Many insects, for instance the Chinch-bug, hibernate in and below such rubbish. By burning this material at a time when the insects are in a torpid condition they are destroyed. If this operation is carried out very late in autumn they are not very likely to find new hibernating quarters, or are thus exposed without any protection to the cold.

PERMITTING HOGS OR OTHER ANIMALS TO GRUB IN ORCHARDS, WINDBREAKS AND TREE GROVES.

Examples:—The large destructive Willow Saw-fly hibernates just under the surface of the soil, or even above it under rubbish. Their larvæ are readily detected and greedily eaten by hogs, skunks and shrews.

CONCENTRATING INSECTS UPON FAVORITE FOOD PLANTS.

This can be done either by causing some plants in the outer rows to appear earlier than the rest, and thus concentrating upon them the great majority of the noxious insects, or by growing some rows of varieties preferred by them. In either case the insects thus concentrated upon a few plants can be much more readily killed then if scattered over a large field.

HIGH CULTURE.

By manuring or by working the soil more thoroughly the plants grown upon it are stronger and more able to recover from damages caused by insects.

Example:—Young plants of wheat, eaten down to the ground by young locusts, will recover and still produce a good crop if the land was in a prime condition.

REFRAINING FOR ONE OR TWO YEARS FROM CROPS BADLY INFESTED.

Example:—Chinch-bugs in our southern counties forced farmers to abandon the growing of wheat for a number of years. Lack of food, and other causes, destroyed the insects, and wheat can again be grown for some seasons.

Rotation of crops has a similar, but not so thorough an effect upon insects.

SELECTION OF VARIETIES LESS LIABLE TO ATTACK.

This is a very important natural remedy, and can be applied in many cases, but in other cases such unpalatable varieties are as yet unknown, and it is the office of the Experiment Station to make the necessary efforts to find them if they can be discovered.

Diversified farming in infested regions is also very important as in this case it is never likely that all the crops will be destroyed, since nearly all insects are dependent for food upon certain plants, and neither can nor will eat others.

Growing of unpalatable crops in place of others greedily eaten is also a similar natural remedy.

LATE SOWING.

This is also an excellent method to prevent certain noxious insects from causing injury, and can be applied in many cases and to various crops.

Example:—Late sowing of peas will prevent the Pea-weevil from depositing eggs upon such plants, because the weevils die before the plants are flowering. Keeping seed-peas longer than one year in a tight sack will have the same effect with most species.

EARLY SOWING.

This, if done properly, will enable the plants to attain such growth and strength as to be beyond serious injury.

LATE PLOWING. EARLY PLOWING.

Both methods are sometimes of great value to protect crops grown upon fields thus treated. Late plowing will disturb and kill many insects that are hibernating in the soil. Tender insects and pupæ that can not move are thus killed. Early and repeated plowing will expose many insects otherwise hidden in the ground to the attacks of birds, shrews and other animals.

Example:—The full-grown larvæ and pupæ of Wire-worms are killed by disturbing the soil late in the fall. Young locusts can not reach the surface of the ground if the eggs are plowed under. Late plowing of fallow land is very important, as such fields attract many insects to deposit their eggs, or to hibernate in the undisturbed soil.

Burning stubble at the proper time is also of great value in a number of cases.

Example:—If the standing stubble, or a layer of dry straw, is burned at a time when young locusts are hatched the majority of them will be destroyed. Dry and dense masses of dead grass harbor many injurious insects, such as Chinch-bugs, and should be burned. By burning the stubble we destroy also injurious insects that hibernate in the culms, such as the Frit-fly.

DITCHING.

To prevent such insects as young Locusts, Army-worms, migrating Chinch-bugs and others from reaching fields as yet free from them, ditches prove of great value since the insects are gathered there and can be destroyed in immense quantities in various ways.

Example:—When Army-worms migrate they usually move all in the same direction. A ditch of sufficient depth will soon trap large numbers, and by means of burning straw, kerosene oil, or by dragging a log along the bottom of the ditch the insects can be destroyed.

ISOLATING FIELDS FROM INSECTS.

This can be done in various ways, depending upon the character of the insects to be kept away.

Example:—To protect a corn field from Chinch-bugs that migrate towards it from fields already devastated, a low fence made of a six-inch board, fastened by pins with its edge upon the ground, and having the exposed edge covered with a fluid mixture of oil and tar, will prevent the bugs from crossing. Even a thick rope saturated from time to time with kerosene oil will prevent them from crossing this slight obstruction. The Chinch-bugs, crowding together in front of this obstacle, can be killed in various ways, best by making holes in the ground with augurs, and to close these as soon as filled with insects, and then to make others to take their place.

INUNDATING FIELDS.

Wherever this can be done farmers have almost complete control over a large number of kinds of noxious insects.

MOWING CROPS EARLY.

This remedy can be applied in a number of cases and with very good effect.

Example:—By mowing timothy badly infested with the Lesser Army-worm at a time when these caterpillars are still young, their food is destroyed and the great majority starve to death. Insects infesting the flowers of red clover can be combatted in a similar way.

Other remedies consist of various devices to prevent destructive insects from reaching their food.

Surrounding stems of young plants with paper or a piece of tin to keep away the cut-worms; tacking a strip of tin or tarred paper around trees to prevent the unwinged females of such moths as the Canker-worm from ascending the trees to deposit their eggs, and other similar contrivances belong here.

INTRODUCING DISEASES

among our injurious insects is receiving now a great deal of attention, and many trials have been more or less successful; yet very much remains to be done in this line of experimentation.

PROTECTING BENEFICIAL MAMMALS, BIRDS AND REPTILES

is one of the best natural remedies we have. It is sad to watch the gradual disappearance of so many of our feathered friends, and the ignorance prevailing in regard to other animals, which are hunted down and killed without mercy, although many of them are our friends. The relation between our wild animals and agriculture has not received that attention which it well deserves. Many animals are considered the greatest enemies of man while in fact they are his benefactors and deserve corresponding treatment.

Many other methods might be enumerated by means of which we can counteract the undue increase of noxious insects, but the above list is sufficient to show that even without the use of poison and machinery much can be done to protect our crops. But we must always study the habits of our enemies, and thus become enabled to select just the one remedy that promises to be effectual. In the warfare against noxious insects there is no royal road which can always be followed.

INTRODUCTION OF PARASITES AND CANNIBAL INSECTS

is also a very promising remedy in some few and special cases. In a state of nature the relationship between plants and insects is so nicely balanced that each species has a number of checks which prevent undue increase. But even there it sometimes happens that such checks become ineffectual from disease or unfavorable climatic conditions, and as a consequence devastations upon a large scale take place. But as a very general rule the disturbed balance is soon restored to its equilibrium. When man imagines he can improve upon nature by adding, purposely or otherwise, a new factor, or by removing one, most unexpected results may follow. For instance the introduction of the European rabbit into Australia was followed by such deep-rooted disturbances between animals and plants that the whole Australian nation is now forced to fight this animal to regain possession of the agricultural products. The introduction of the English sparrow into the United States is another example, and has already been of sufficient influence to disturb the ancient order of things. So it is with the accidental introduction of foreign noxious insects, as our farmers have learned to their sorrow. As such recently introduced species are usually not accompanied by their enemies these latter ought to be introduced after careful consideration of the case in all its bearings.

To the natural methods to prevent the undue increase of noxious insects might be added proper *laws*. People unwilling to do their share in preventing losses caused by insects ought to be forced by carefully prepared laws to do their duty, if not to themselves, at least to their neighbors and to the community at large. Insects that threaten to become a serious danger to the inhabitants of a whole state should be considered as a public calamity, like some contagious disease, and should be suppressed by every known means.

ARTIFICIAL METHODS,

based upon the structure of insects, are now used very extensively and in most cases with good results. For insects with a biting mouth arsenical poisons are chiefly used. Other poisons are less general in use, but are of great importance in special cases. Insects with a sucking mouth can not be reached with poisons that become active only in their digestive tracts, although some, if applied to soft-skinned species, kill them by contact. Vital organs of sucking insects have to be reached through their skins, either with substances that penetrate through it, or bo closing their spiracles, or by otherwise irritating them to such an extent that they become disabled. Other insecticides combine these properties and still others become active by generating injurious and fatal gases and fumes.

Paris green, London purple and white arsenic are mineral compounds of arsenous acid, and consequently very poisonous to all organized matter. To use them properly we must recollect that plants can be poisoned by them as well as anlmals, and that they have to be diluted in certain proportions with other substances to make them harmless to plants and yet keep them poisonous enough to kill such insects that eat the foliage covered with them.

PARIS GREEN.

is a chemical combination of arsenious acid and copper, and is called by chemists arsenate of copper. It contains, when pure, about 58 per cent. of arsenious acid. Pure it is insoluble in water, and can be applied either as a dry powder mixed with other substances, or suspended in water. As plants are affected in different degrees by this poison the exact proportions of it and the dilutents can not be given except in a general way. Some plants, as the potato, can be dusted with quite a large amount of it without being greatly injured, while the same amount would kill many other plants, as the plum-trees. Plants made sensative by certain climatic conditions, as by continuous moist and warm weather without sunshine, suffer at such times much more severely by an application of this and similar insecticides than at others. Before applying any arsenical poisons to plants upon a large scale it is always best to try their effects upon a few, so that the mixture can be made just strong enough to kill the insects and not to injure the plants. It has been found that milk of lime almost entirely prevents the injurious effects of arsenical poisons upon the foliage. The addition of a little flour has also a similar benefisial effect and is also of some use in retaining the poison upon the leaves. Milk of lime can be prepared by filling a barrel nearly full of air-slacked lime, and adding to it sufficient water to fill it entirely. After standing undisturbed for some time the clear water above the lime is milk of lime. This can be demonstrated by blowing air from our lungs through it when it will become milky.

DRY APPLICATION.

As a general rule Paris green should be mixed with one hundred times its weight of perfectly dry flour, sifted wood ashes or road dust, land-plaster, air-slacked lime or similar substances. To apply this dry mixture successfully it is necessary to dust it over the plants at a time when there is no wind, and when the leaves are moist, as they usually are very early in the morning. In this case most of the dust will adhere to the leaves and remain there for a long time. Still any dry application, except upon a small scale, is always a very wasteful one.

WET APPLICATION.

One pound of Paris green to 150 gallons of water is a safe mixture with which to kill nearly all insects that possess a biting mouth; it will not kill the foliage of any cultivated plants grown in Minnesota. If it should become necessary to spray the same plants repeatedly later applications may be reduced in strength. As Paris green does not readily mix with water it should be first made into a paste, and this should be mixed with the amount of water required. Upon the leaves of some plants this fluid will not adhere, as upon the leaves of cabbage. In this case we can overcome the difficulty by adding a little dissolved soap to the mixture.

LONDON PURPLE.

This by-product in the manufacture of aniline colors contains about 43 per cent of arsenite of lime, the rest is composed of Rose aniline, lime, insoluble residue, some little oxide of iron and water. As the material is cheap it would be used much more frequently if it came in convenient packages and not in bulk. At all events it is just as good an insecticide as Paris green, and can be used in the same manner, dry and with water. It is much lighter than Paris Green, more finely divided, remains better in suspension in water, and can therefore be applied more evenly, with less stirring, adheres better to the foliage, and is consequently not so readily blown away by the wind or washed down by rains. As most of the commercial London purple contains some free and soluble arsenious acid we must add some milk of lime to prevent injury to the foliage. If this precaution is kept in mind we have in this substance a very superior insecticide. It has this additional advantage, that it can be used with the Bordeaux mixture and we can add to its effects as an insecticide that of a fungicide. If Paris green is used for a similar purpose we are very apt to increase its injury upon foliage.

A very good proportion in which to apply London purple is one pound to 200 gallons of water, with an addition of about one pail full of milk of lime. It is always well to mix London purple with the water just before use, and not to leave the mixture standing over night, as may be done safely if Paris green is used. In a dry application we can dilute this insecticide with the same substance as we used with Paris green.

In certain cases, as against the Codling moth, both Paris green and London purple must be applied to the trees before the eggs have been deposited by this insect. By doing so the young larvæ, before reaching the interior of the fruits, have to eat their way through the skins and by eating some of the poisonous material coating the fruit are killed.

WHITE ARSENIC.

White arsenic though very cheap, is too dangerous to use, being more readily mistaken for some edible substances on account of its white color, and also because it is more injurious to foliage, as it is to some extent soluble in water. If it has to be used it should be very much diluted, and the mixture should be applied while quite freshly mixed, and only with a large amount of milk of lime.

In using such virulent poisons as Paris green, London purple and White arsenic it is important to keep in mind the following rules: label the stored material very plainly "*Poison*"; do not handle the poison with your hands; never apply it against the wind; do not use it upon leaves or fruit soon to be eaten; and use it of no greater strength than is absolutely necessary. The following doses of arsenic are dangerous: two grains for an adult, thirty grains for a horse, ten grains for a cow, one-half to one grain for a dog. In cases of poisoning treatment is never hopeless. For persons, give hot milk and and water and tickle the throat with a feather to induce free vomiting. Sugar and magnesia in milk is also a good antidote. Another remedy is also readily prepared: Pour together solutions of Perchloride of

Iron and dilute ammonia; the brown percipitate that forms should be strained off and given with water.

WHITE HELLEBORE.

White hellebore acts both as a poison and as an external irritant. It is a vegetable poison, being a powder made from the roots of an European plant, the *Veratrum album*. Though less poisonous to man and animals it is dangerous to them when fresh; later it seems to loose to a great extent its poisonous qualities. But it is quite harmless if applied to even tender foliage, and is the best insecticide we possess against slugs and false caterpillars, the larvæ of our noxious saw-flies. It can also be applied as a dry power well mixed with such substances as dry road-dust and air-slaked lime, or with water. The usual proportion of a liquid mixture is one ounce to two gallons of water. The insects die when brought in contact with this mixture, or if they eat it with the leaves upon which it is dusted or sprayed.

PERSIAN OR DALMATIAN INSECT-POWDER, PYRETHRUM OR BUHACH.

This is also the product of a number of foreign plants belonging to the genus *Pyrethrum* of the composite plants, which resemble our May-weed. Though almost perfectly harmless to plants and to higher animals it is fatal to insects, at least to all not thoroughly well protected by a very tough skin. It can also be used in the form of dry powder, or suspended in water. It seems that the dry application has the most market effect, and for this purpose it should be mixed with about four times its weight of some finely sifted dilutent. To obtain the best results this mixture should be kept for one or more days in an air-tight vessel before using it. It seems to paralize many insects with which it comes in contact. If used wet the best proportions are one ounce to two gallons of water. This insect-powder is now prepared to some extent in California, where it is called Buhach. Though an excellent insecticide it is very apt to give no satisfaction, as in our markets it is not only very much diluted, but is so poorly cared for that even the unadulterated material soon becomes almost worthless. The powder should always be kept in an air-tight tin box, otherwise its active principle, an essential oil, will soon escape. As it is, some of our retail druggists expose it in open barrels in their show windows with flaming posters to attract purchasers. Of course if kept in this manner it looses all virtue as an insecticide. In Europe they keep the dried flower-heads until the powder is needed, when they are ground fine. Insect-powder, when pure and fresh, if dusted in a room or stable filled with flies or mosquitoes, will soon kill them. It can also be utilized in the form of tea, as a decoction, as an alcoholic extract, or as a fume, and will be found very useful in certain cases.

TOBACCO.

This well-known plant is a very useful remedy against a number of soft-bodied insects. In green-houses it is a great favorite with gardeners against the insects found there. A decoction, made by boiling a pound of tobacco stems in one gallon of water is a very effective remedy against such insects as flea-beetles and plant-lice. In the form of fine dust it is also of great value against the more tender insects or larvæ. As tobacco stems are very cheap, and are also quite valuable for fertilizers, a more general use of this insecticide is adviceable. As a wash for animals infested with vermin it gives good results, but is inferior to kerosene-emulsion.

FISH-OIL SOAP. WHALE-OIL SOAP.

Both soaps can be bought very cheap, and as they are useful for many purposes ought to be kept ready at hand. Suds made of one pound of such soaps in eight gallons of water are very effective against a large number of soft insects, but chiefly against leaf-lice which succumb very readily. Soft soap, boiled down to the consistency of thick paint forms a tenacious coating for the bark of trees and prevents insects, like borers, from depositing their eggs. If mixed with a little Paris green or London purple it becomes still more effective.

CARBOLIC ACID. COAL TAR. AIR-SLAKED LIME, PLASTER AND WOOD-ASHES.

Carbolic Acid, and the various mixtures that can be made with it have not proven very good insecticides, yet in special cases they may be used with good results.

Coal-tar is very useful in some cases, not so much as an insecticide but as a repellent and as a means to capture the still unfledged locusts in "hopper-dozers."

Air-slaked lime, plaster and wood-ashes have also some value, and by thoroughly dusting plants infested with soft or slimy bodied insects, many of the latter are killed. Besides, these substances are good fertilizers.

KEROSENE-EMULSION.

Kerosene-oil, though used but for a comparatively short time as an insecticide, has a greater range of usefulness than any other one. It is not a poison but kills by contact. It is a very penetrating fluid and causes almost instant death. But since it kills plants as well as insects it can not be used alone but has to be mixed with some substance that dilutes it without impairing its value as an insecticide. A number of methods are known in which this may be done. One of the best is the "Hubbard formula," which is given below:

"Kerosene, 2 gallons	67 per cent.
Common soap, or whale-oil soap, ½ ℔... Water, 1 gallon	33 per cent."

Heat the solution of soap and add it boiling hot to the kerosene. Churn the mixture by means of a force pump and spray muzzle for five or ten minutes. The emulsion, if perfect, forms a cream which thickens on cooling, and should adhere without oiliness to the surface of glass. Dilute before using one part of the emulsion with nine parts of water. The above formula gives three gallons of emulsion and makes, when diluted, thirty gallons of wash." This emulsion is an excellent one when the water used is soft. But with hard water the formula given by Cook is equally good, and for some parts of Minnesota it is better. It is here repeated: "Dissolve one quart of soft soap in two quarts of boiling water. Remove from fire, and while still boiling hot, add one pint of kerosene oil, and immediately agitate with the pump as described above. In two or three minutes the emulsion will be perfect. This should be diluted by adding an equal amount of water, when it is ready for use. This always emulsifies readily with hard or soft water; always remains permanent, for years even; and is very easily diluted, even in the coldest weather, and without any heating."

All sucking insects that can not be reached by making them eat poisons can be killed by an application of one of the above emulsions. It is most valuable against all kinds of leaf-lice and most scale insects, which latter can not be reached in any other way since they are so well protected by their scales or downy or woolly secretions. Against the various insects infesting the skins of our domestic animals nothing better has as yet been found. Even the hidden scab-mites of sheep readily yield to it. For forming a film upon the surface of rain water in barrels to prevent the breeding of mosquitoes the unmixed oil is best, though any oil will suffice.

BISULPHITE OF CARBON.

There are a number of insects that can not be reached by any of the insecticides mentioned thus far. Insects, for instance, that destroy our stored grain, must be fought by another method, and the above fluid has been found very effective for this purpose, and as it is perfectly harmless to the grain itself no injury can follow if it is applied properly. This fluid is a very volatile substance and its fumes penetrate everywhere. By closing the room containing the stored grain as tight as possible, and by filling this space with the deadly fumes all animal life will soon cease to exist. As the material is inflammable it should never be used near a fire. It is also dangerous to inhale much of it. It is also very useful against other insects that live in the ground, for instance against ants. Even the pocket-gopher can be killed by filling its burrow with such fumes.

Gasoline, *Benzine*, *Oil of Turpentine* and similar volatile substances are also effective if applied to household pests that hide in cracks. Substances such as *Naphthaline*, *Camphor*, *Sublimate of Mercury*, *Powdered Borax*, *Sulphur* and others might be mentioned as insecticides for special cases.

MACHINES TO APPLY INSECTICIDES.

To use any of the insecticides mentioned above three rules should be followed:

1. Never apply more than is absolutely necessary, because otherwise expenses will be greatly increased, and instead of protecting our plants we might injure them.

2. Never wait until too late. Apply as soon as the causes of the injury are recognized.

3. Always apply the insecticides as uniformly as possible, cover all parts of the plants, both the upper and lower surfaces of the leaves.

As it is not possible to reach all parts of the plants except by means of some specially devised machine, every farmer and fruit grower should possess a spraying machine. Many excellent kinds are now in the market, and the more simple ones are so cheap that the question of expense is of little importance. In buying, attention should be paid to the uses for which the machine is needed, for instance, whether trees or low-growing plants are to be protected. At all events, every machine should have, besides the usual pipe leading to the nozzle, another return pipe, which carries at every stroke of the pump handle a stream back into the tank holding the poison in suspension, otherwise this will settle at the bottom and only the clear and harmless fluid is sprayed over the plants. A second and very important point is to select a good nozzle, one that will not simply sprinkle the fluid over the plants, but that will divide it into such minute parts as to form a genuine spray. Bearing these two necessary qualities of a good force pump and spraying machine in mind the purchaser will have no great difficulty in selecting one that is suitable for his purposes.

In closing this bulletin I should like to add that the entomologist of this Experiment Station is not only willing but anxious to assist all farmers in their war of extermination against noxious insects. In order that he may do so effectually farmers seeking advice should always send specimens of the insects which trouble them, with specimens of their food-plants and also any observations they may have made. Otherwise the entomologist cannot be certain which one of the many species of noxious insects is the real culprit.

OTTO LUGGER.

NOTE.—Most of the illustrations are copied from the superb works of Prof. Dr. E. L. Taschenberg. Fig. 45 and 67 were purchased from C. V. Riley. Fig. 57 was kindly loaned by H. Gorman; and still others are original.