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Artikel: Pests of crops in warm climates and their control
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I. Introduction

1. STRUCTURE, GENERAL CHARACTERISTICS AND DEVELOPMENT OF INSECTS

The bodies and members of insects are covered with a very resistant integument, varying in thickness and made of a hard substance known as chitin, which not only protects the insects against chemical and mechanical influences but also constitutes their external skeleton. Since the body wall can expand only very little, the skin has to be shed periodically during larval growth. Special glands lying under the skin in a layer of living cells secrete a substance which enables the larva to cast the old and form a new skin. When the adult stage, or imago, is reached, moulting ceases.

External Morphology of Insects

The body of a fully developed insect is divided into three distinct regions: *head, thorax* and *abdomen* (see Fig. 1). The head bears the antennae, the eyes and the mouth parts. The *antennae,* always a pair, are borne on the forehead; they are composed of a string of segments and are used for feeling and smelling. They vary greatly in shape, and this wide variation is an important factor in entomological classification.

The eyes are either simple (ocelli), or compound (facetted). The *compound eyes,* borne on either side of the head, are immobile and consist of wedge-shaped, independent eyes having a hexagonal area, called the facet, each of which comprises a lens and cornea. Since each individual eye reflects only a small portion of the insect's surroundings, the objects are seen as a mosaic pattern. The *ocelli* appear as small, dark, brilliant and often convex epidermal structures on the forehead; they serve to distinguish dark from light. Lower insects as well as the larvae of many insects with complete metamorphosis often have *only* ocelli; adult stages of higher insects usually have both types of eyes.

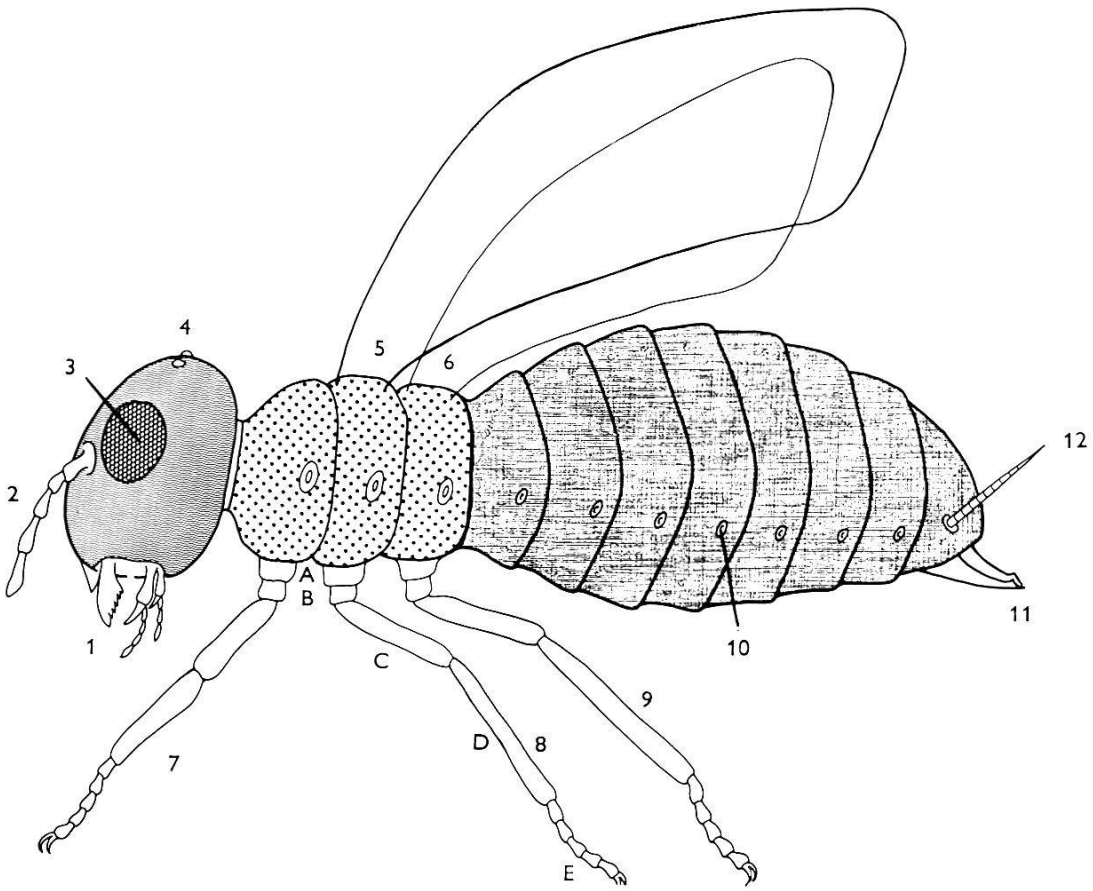


Fig. 1. External morphology of an insect (diagrammatic)

Head
1 = mouth parts
2 = antennae
3 = compound eye
4 = ocelli

Thorax
(pro-meso- and meta-thorax)
5 = forewings
6 = hindwings
7 = fore-
8 = mid-
9 = hind-
leg
A = coxa, B = trochanter, C = femur, D = tibia, E = tarsi

Abdomen
10 = spiracle
11 = gonapophyses (ovipositor)
12 = cerci

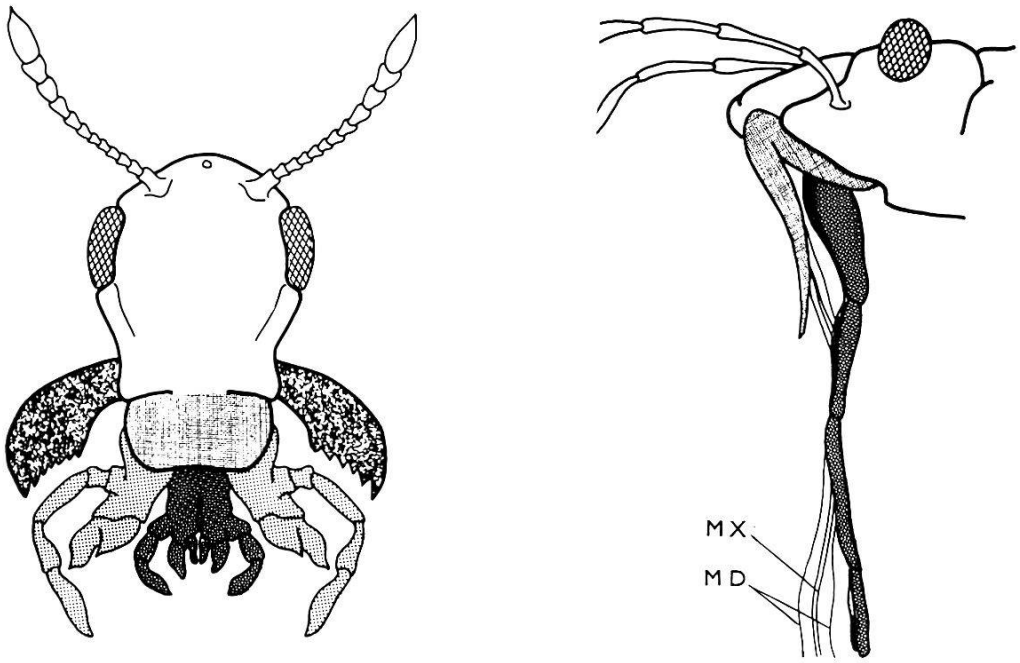


Fig. 2. Mouth parts of insects (diagrammatic)

left: the biting-chewing type
right: the piercing-sucking type

upper lip (labrum)

upper jaws (mandibles = MX)

lower lip (labium)

lower jaws (maxillae = MD)

Most insects injurious to plants have either *biting-chewing* or *piercing-sucking mouth parts*. The former are fitted for taking solid food, the latter for liquid.

The mouth parts are grouped around the mouth cavity, and biting-chewing insects (see Fig. 2), such as beetles, grasshoppers, crickets and many larvae have their mouths partly covered by the *upper lip (labrum)*. Immediately below, left and right, are the robust, usually saw-toothed *upper jaws (mandibles)*, fitted for seizing and tearing. Further below is a second pair of jaws, the *lower jaws (maxillae)*, furnished with segmented appendages, the *maxillary palps*. They serve to grind and masticate food previously cut off with the mandibles. The single *lower lip (labium)* closes the mouth below; it is lobed and also bears appendages, known as *labial palps*.

The structure of piercing-sucking mouth parts (see Fig. 2) is quite different. Both *upper* and *lower jaws (mandibles* and *maxillae)* are developed into slender, hair-like stylets. The two inner stylets, formed by the maxillae, are joined together so as to form two separate channels or grooves. One channel contains the saliva flowing into the sting, while the other serves to bring the liquid food into the mouth. When not in action the two pairs of stylets lie in the tubular, segmented *lower lip*, which is cleft along the upper side. The *upper lip* is a short and narrow flap which covers the base of the beak. Plant-sucking insects, such as bugs, leafhoppers, aphids, and

others thrust their stylet into the plant tissue and suck the plant sap; during this process the lower lip is curved back at the piercing point.

Other types of mouth parts such as those of nectar-sucking butterflies or licking-sucking bees, wasps, and flies are also arranged in a manner suitable for their particular mode of food uptake.

Butterflies have their sucking tube formed by the *lower jaws* coiled downwards, while the usually rudimentary *upper jaws* show as humps on both sides of the base of the coiled tube. The length of the tube is adapted to reach the nectar inside the flowers.

Bees have rather indistinct *upper jaws*. They suck up liquid food (nectar) with their *lower lip* developed into a long, ringed, tongue-like tube, spoon-shaped at the tip. Wasps and ants have strong *upper jaws* but only a short lapping tongue formed by the *lower lip*.

The beak of licking-sucking flies is also formed by the *lower lip*, the tip of which, the so-called *labella*, is pestle-shaped. The labella is traversed by numerous channels through which, when the flies feed, the saliva flows on to the food which is drawn up again later on as liquid and brought into the alimentary canal.

The choice of control measures against insects depends greatly on the structure of their mouth parts. Poison or contact insecticides can be applied against chewing and licking-sucking species, while contact, penetrating and systemic insecticides are effective against piercing-sucking species.

The *thorax* is formed of 3 segments: *pro-, meso-, and metathorax* (Fig. 1). Each of the three thoracic segments bears one pair of *legs*, and the *wings*, usually two pairs, are inserted in the meso- and metathorax. Shape and venation of wings vary greatly and are important characteristics for identification. In some insect groups the number of wings is reduced. Flies and midges have only membranous forewings, while their hindwings are modified to form small, club-shaped direction-finding organs, termed *halteres*. Some butterflies and beetles have only small wing rudiments.

The legs of insects have a more or less uniform structure. They are composed of the following parts: *coxa, trochanter, femur, tibia,* and *tarsus* (see Fig. 1). According to the habits of an insect the extremities of the legs have become adapted either for walking, digging, swimming, leaping or gathering.

The *abdomen*, devoid of legs, is composed of several segments. The caudal segment is often extended into an *ovipositor* with which the female lays its eggs; sometimes it bears external *genital outgrowths* of various shapes, called *gonapophyses*, and jointed appendages called *cerci*.

The segments of the body are joined together by a thin skin, the so-called *intersegmental membrane* which gives the insects great flexibility.

It will be seen from this definition what the entomologist calls "*insects*". There are other organisms resembling them which, though they belong to another class of arthropods, are often mistaken for insects, and are therefore included here. These are *mites* and *spiders*, the head and thorax of which are grown together to form the so-called *cephalothorax*. Early stages of these arthropods have 6, later stages usually 8 legs. (The economically important *Eriophyid* mites have only 4; see Fig. 45). *Millipedes (Diplopoda)* and *centipedes (Chilopoda)* also differ from insects in having a great number of legs all along the body (see Fig. 45).

Anatomy and Physiological Functions of Inner Organs

(see Fig. 3)

The *alimentary canal* consists of three sections: fore-, mid-, and hind-intestine. While in the fore-intestine chemical transformation of food stuffs (proteins, carbohydrates, fat) is started, in the mid-intestine the digestive fluid is secreted, which makes the food absorbable. In the hind-intestine undigestible food remains are thickened and then egested. Fore- and hind-intestines are of the same origin as the body wall. In larval stages the membrane of these intestinal sections is periodically cast off together with the external skin. Food uptake is thus interrupted for 1-2 days during moulting.

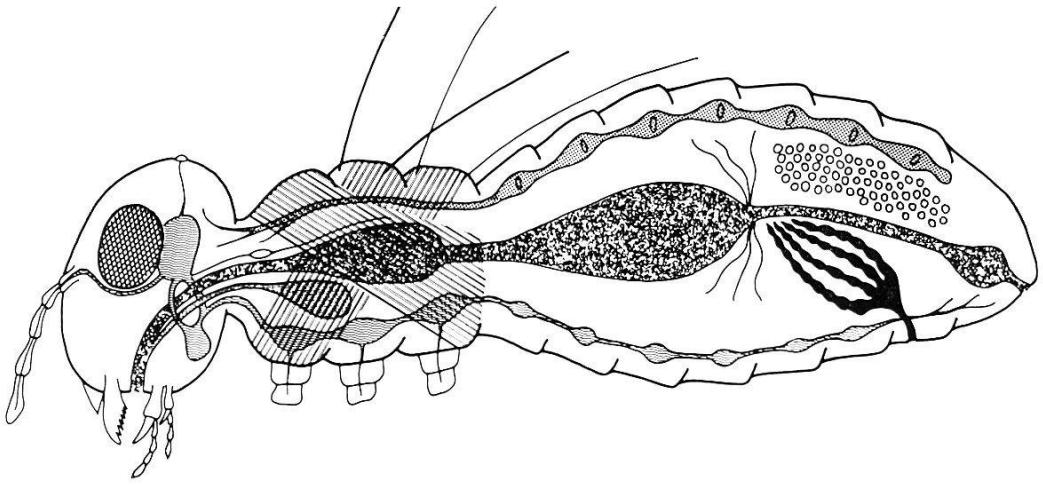


Fig. 3. Internal arrangement of the principal organs of an insect (diagrammatic sagittal section)

alimentary canal (fore-, mid-, and hind-intestine)

salivary gland

heart

Malpighian tubes

nervous system

thoracic muscles

reproductive organ (ovary)

fat body

The *heart* is a tubular sac, which contracts rhythmically and lies dorsally along the middle of the abdomen. The blood, which is usually colourless, flows freely towards the head; later the blood is admitted again to the abdomen and sucked back into the heart through lateral openings termed *ostia*. A closed system of blood vessels, as found in higher animals, is thus absent in insects; their circulatory system is open. The function of the blood is mainly to distribute food and hormones to those parts of the body where they are needed.

Organs of secretion are the so-called *Malpighian tubes*, a great number of small vessels between the mid- and hind-intestines, through which products of digestion are carried from the blood into the hind-intestine.

Insects have no proper lungs. They breathe through a network of widely ramified tubes called *tracheae*, through which the air can enter directly into the organs which these tubes envelop. The openings of the tracheae, called *spiracles*, are placed on either side of the thoracic and abdominal segments. Respiration is accomplished by alternate movements of the abdomen. The tracheae are lined with strong chitinous spirals which prevent them from being squashed.

The *nervous system* of insects begins in the head with the *brain* and the *suboesophageal ganglion* and runs vertically through thorax and abdomen as a double cord, thickened at short intervals (in each segment) to the so-called *ganglia*. The thoracic ganglia are usually fused together so as to form the nerve chain. A number of nerves link the brain with the eyes and antennae, the suboesophageal ganglion with the mouth parts, while the thoracic ganglia are connected with the legs, wings and abdominal organs. Hundreds of hairs and bristles covering the body are highly sensitive sense organs.

The *sympathetic nervous system*, controlling physiological processes in the body, lies dorsally above the fore-intestine.

The *muscular system* is particularly well developed in the head and thorax (muscles moving mouth parts, wings and legs); the muscles are fixed to the inner surface of the body wall.

The internal *reproductive organs*, especially the *ovaries*, together with the *fat body* enveloping them, lie in the abdomen. The fat body, consisting of fat cells accumulated during larval development, serves many insects as a food reserve, enabling them to survive even prolonged periods of starvation.

Forms of Development

Insects are usually either male or female and thus reproduce sexually. Most species are oviparous, i.e. they lay eggs, from which the larvae emerge. Some species, such as aphids, are viviparous: they

produce living larvae. Another way of reproduction is parthenogenesis, as in aphids, mealybugs, and coccids. It is characterized by the absence of the male element, the eggs developing without being fertilized.

Larval stages of insects differ more or less from adult stages by their structure, biology and nutrition. A common characteristic of larval stages is the periodical moulting during their development and the changing of form before they reach the adult stage. This process is known as metamorphosis.

The three types of development of insects are:

1. **Ametabolous development.** All stages are wingless and there is no pupal rest. The adult stage is reached without metamorphosis.

   Examples: Collembola (springtails), Thysanura (bristletails).

2. **Hemimetabolous development or incomplete metamorphosis.** The larval stages resemble the adult form with regard to the structure of their body. After the penultimate moulting, wing rudiments are present, and when fully developed, after the last moulting, proper wings are formed and the insect is sexually mature. There is no pupal rest. Nutrition is similar in all stages.

   Examples: Orthoptera (grasshoppers), Heteroptera (bugs), Homoptera (cicadas, psyllids, plant lice).

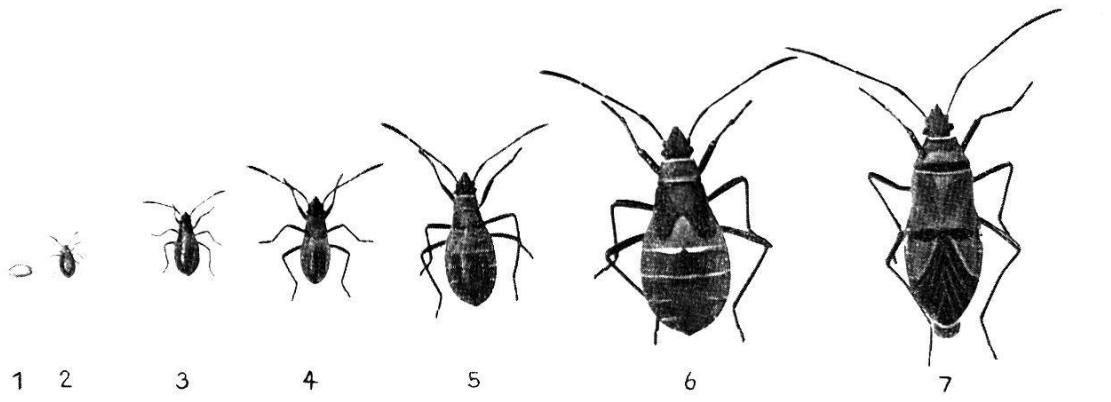


Fig. 4. Incomplete metamorphosis in *Heteroptera*

The Cotton stainer, *Dysdercus fasciatus*
1 = egg; 2-6 = first-fifth stages; 7 = adult

3. **Holometabolous development or complete metamorphosis.** From the egg emerges a worm-like, wingless larva, maggot or caterpillar, bearing no resemblance to the adult form. After moulting several times the larva reaches its full size, ceases to feed, and forms an

immobile pupa, often spun into a cocoon. During this quiescent stage transformation of the larval organs takes place. In caterpillars, for instance, the biting mouth parts are modified to become sucking ones at the moment when the mature winged moth or butterfly emerges from the pupa.

Examples: Lepidoptera (butterflies), Coleoptera (beetles), Diptera (flies), Hymenoptera (bees, wasps, ants).

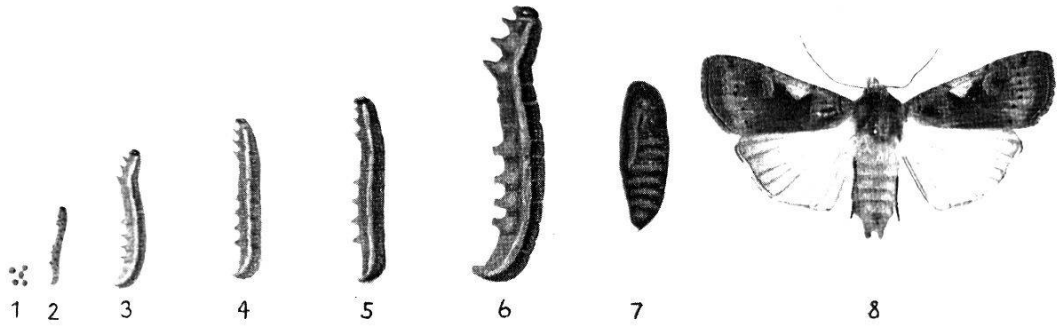


Fig. 5. Complete metamorphosis in *Lepidoptera*

Agrotis c-nigrum, an owlet moth
1 = eggs; 2-6 = larval stages; 7 = pupa; 8 = moth (adult)

According to their outward appearance insect larvae with holometabolous development can be grouped as follows (see Fig. 6, a-d):

a. **Acephalous-apode larvae**
Head capsule indistinct; only buccal hooks present. No thoracic or abdominal legs; merely creeping pads.
Example: fly maggots.

b. **Eucephalous-apode larvae**
Well developed head capsule. No thoracic or abdominal legs; only creeping pads.
Examples: larvae of weevils and bark beetles.

c. **Eucephalous-oligopode larvae**
Well developed head capsule. Each thoracic segment with one pair of legs. No abdominal legs.
Examples: larvae of beetles such as grubs, wireworms.

d. **Eucephalous-polypode larvae**
Well developed head capsule. Thoracic segments with legs; abdominal segments with non-segmented, so-called prolegs.

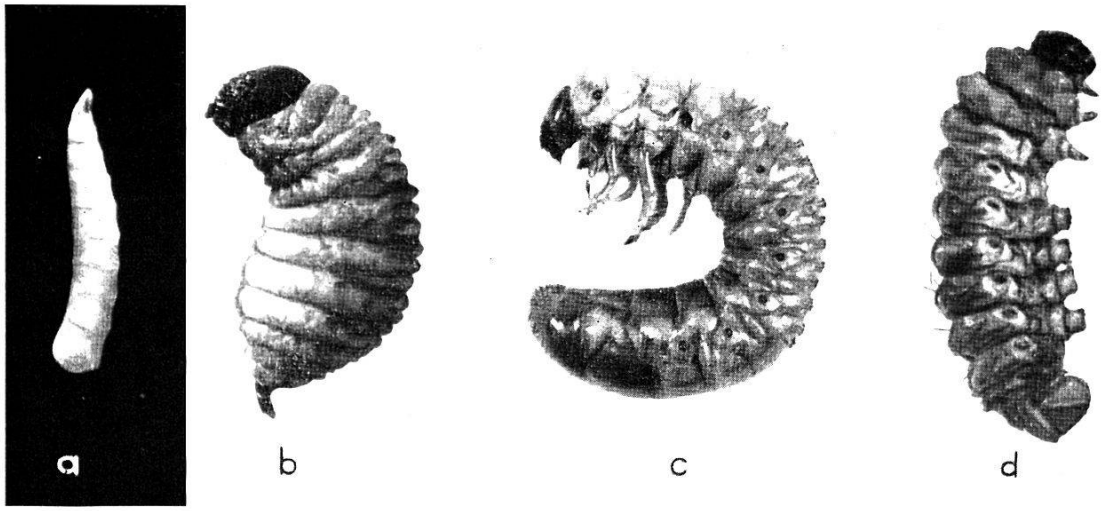


Fig. 6. Different types of insect larvae

Three types of pupae can be distinguished (see Fig. 7, a-c):

a. **Exarate pupae = pupa libera**
Appendages such as wing sheaths, legs, antennae and mouth parts sharply margined.
Examples: beetles, Hymenoptera.

b. **Obtected pupae = pupa obtecta**
Wing sheaths, legs, antennae and mouth parts glued with exuvial fluid to the body. Pupae free or protected by webbing.
Example: butterflies.

c. **Coarctate pupae = pupa coarctata**
Pupae enclosed in a solid case. Last larval stage pupating inside a hardened, strongly pigmented larval skin.

Example: flies.

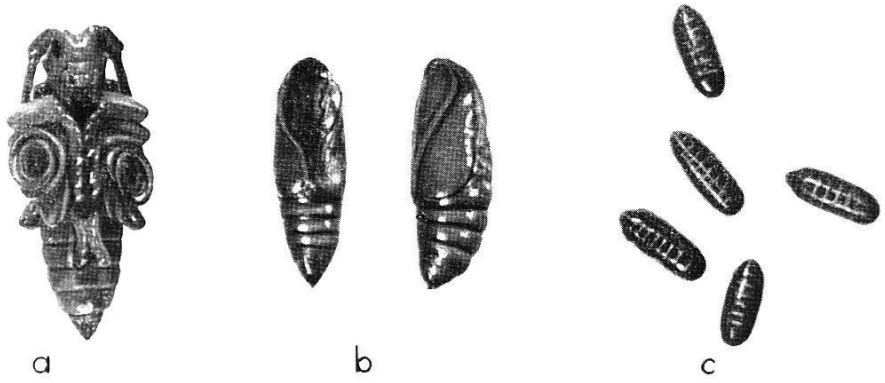


Fig. 7. Different types of pupation

2. SYNOPSIS OF THE CLASSIFICATION OF THE MOST IMPORTANT PLANT PESTS

INSECTA

The class Hexapoda or Insects is divided into numerous orders. The following illustrations, accompanied by very short and concise descriptions of some of the main representatives may serve as an introduction to the most important orders and families of insects injurious to vegetation. For easy reference, a typical representative of each family is illustrated. The adult winged insect is shown alone, or with its larva. References relating to natural size are attached to illustrations, where necessary. The illustrations of some of the pests in this chapter will be found in chapter III. In these cases a reference to the relevant illustration (indicated as No.) is given.

Order Orthoptera

cockroaches, crickets, mole-crickets, earwigs, locusts

The members of this order are free-living, terrestrial, medium to large-sized insects. Their mouth parts are fitted for biting and chewing. The forewings are leathery and often cover the transparent, closely folded hindwings. The habits and life history of larvae and adults are similar. The development of Orthoptera is hemimetabolous.

FAMILY BLATTIDAE

cockroaches

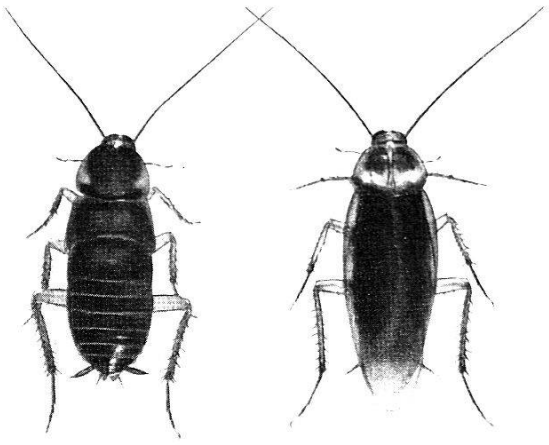


Fig. 8

The body is more or less flattened; the head has long, thin antennae. The posterior end of the abdomen is furnished with caudal appendages (cerci). The legs have 5 tarsal segments. Cockroaches are usually found in storage rooms, where they hide in dark places, feeding on vegetable and animal matter. They deposit their eggs in cushion-shaped cases. Although troublesome in houses, members of this family are of no importance in agriculture.

FAMILY GRYLLIDAE

crickets

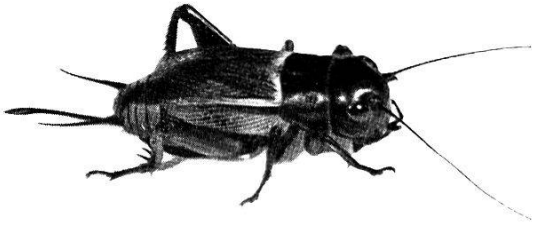


Fig. 9

The body is cylindrical; the head strongly developed, bearing long, slender antennae. The posterior end of the abdomen has two caudal appendages (cerci). The legs have 3 tarsal segments. The females are provided with an ovipositor. Crickets live in underground burrows, where they feed on plant particles and on small insects. By rasping the two forewings together they produce a chirping sound.

FAMILY GRYLLOTALPIDAE

mole crickets

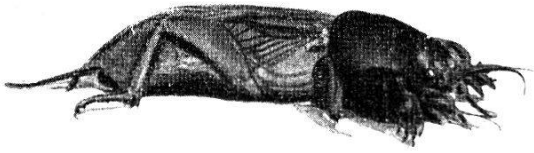


Fig. 10

Body usually dark brown to reddish-brown. The head bears long, thin antennae. The forewings are short and broad, while the hindwings are rolled up to form pointed processes which extend beyond the abdomen. The latter has two appendages (cerci). The females have no ovipositor. Mole crickets live underground in earth galleries, where they feed on plants and animals.

FAMILY FORFICULIDAE

earwigs

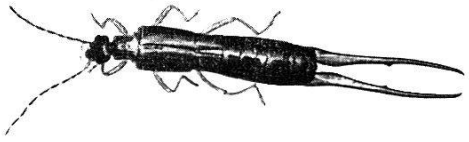


Fig. 11
(⅓ enlarged)

Blackish-brown, flat insects with two strong forceps-like appendages at the caudal end. The antennae are long and slender. The small, stumpy forewings cover part of the hindwings which are bent under them. Oviposition takes place underground in earth tubes. Earwigs feed on plants, often attacking the flowers.

FAMILY TETTIGONIIDAE

long-horned grasshoppers

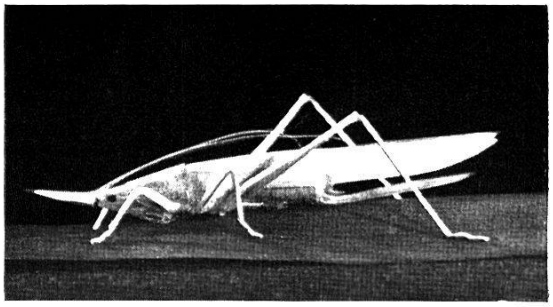


Fig. 12
(½ reduced)

Grasshoppers with long, thin antennae, the segmentation of which is hardly visible. The tarsi are 4-jointed. When at rest the rigid forewings cover the membranous hindwings which are folded fan-like. The females have a strong, sword-like ovipositor, while the males have two short appendages. The male produces a chirping sound by rasping the left forewing (elytrum) over the right one. Insects of this family have diurnal habits. They lay their eggs in the soil and feed on plants and insects.

FAMILY ACRIDIIDAE

see page 451, Fig. 60

locusts, or short-horned grasshoppers

As the name indicates, the antennae are short. The last abdominal segment bears two short bristles and the females have no ovipositor. The tarsi are 3-jointed. The males produce a chirping sound by rubbing the file-like inner side of the femur against the prominent radius of the forewing. The females lay their eggs in the soil. Locusts are diurnal insects and feed ravenously on plants. Some species form swarms (see page 450).

Order Isoptera

termites

see page 458, Fig. 62

Polymorphic insects, living in colonies.

Order Thysanoptera

thrips

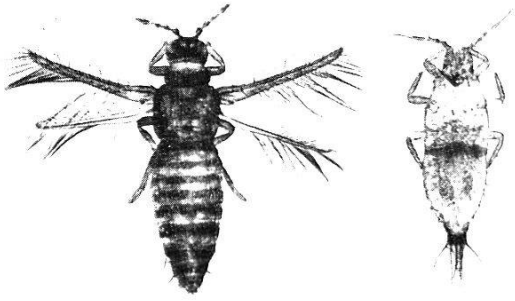


Fig. 13
(10× enlarged)

Minute, slender insects, heavily sclerotized, usually yellow to dark brown in colour. The mouth parts are fitted for piercing and sucking,

The forewings are fringed with long hairs along the margins. The tarsi consist of 2 segments with a large bladder, regulated by blood pressure, at the tip. The development of Thysanoptera is hemimetabolous (remetabolous); they reproduce either sexually or parthenogenetically. Thrips are usually injurious to vegetation. Some species, however, are predatory, feeding on other small insects.

Rhynchota

comprising the Orders Heteroptera = *true bugs*
and Homoptera = *cicadas, leafhoppers, aphids, scale insects, and others*

Insects belonging to these orders have beaks with mouth parts fitted for piercing and sucking. The snout-like beak arises from the front or from the underside of the head; it is usually straight, 4-jointed and its sheath is formed by the labium. The sucking apparatus, enclosed in the beak, consists of 2 mandibular and 2 maxillary bristles or stylets (cf. also Fig. 2). The prothorax is usually free. The development of Rhynchota is hemimetabolous.

Order Heteroptera

true bugs

The head can be moved freely. The beak arises from the tip of the head. The thorax has a distinct, often large scutellum (see Fig. 14).

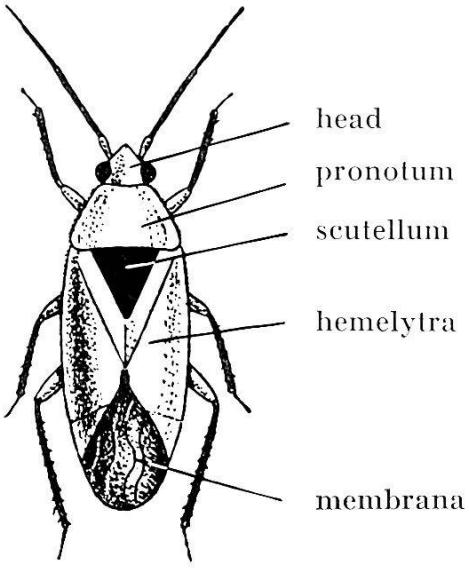


Fig. 14. A bug of the Order *Heteroptera*

When at rest the wings rest upon the body and do not cover the scutellum. The forewings are developed into fairly thick covers termed hemelytra. The basal part is leathery, while the upper part is membranous and often transparent (membrana).
Both larvae and adults have similar life habits.

FAMILY PENTATOMIDAE — see Chapter III Nos. 248, 249, 481, 483, 622, 691, 842

stink bugs

Medium- to large-sized, stout, more or less convex bugs with thin, 5-jointed antennae. The scutellum is large and the membrane veined. The eggs are fixed in clusters to the plants or laid underground.

FAMILY COREIDAE — see Chapter III Nos. 352, 378, 484, 529, 605, 606, 743

squash bugs

Medium- to large-sized, stout bugs, with 4-jointed beak and antennae. The scutellum is relatively small; the membrane is veined. The femora of the hind legs are often thickened or flattened. The eggs are fixed either in clusters or singly to the plants.

FAMILY LYGAEIDAE — see Chapter III Nos. 252, 676, 843

chinch bugs

Relatively small and flat, variegated bugs, the antennae and beak of which are 4-jointed. The scutellum may be fairly large in some species. The membrane is veined and the legs are thin. The eggs are deposited on the plants.

FAMILY PYRRHOCORIDAE — see Chapter III No. 879

stainers

Usually large bugs, elongate-oval in outline and vividly coloured. The 4-jointed antennae are slender. The beak also is 4-jointed, long and thin, held against the ventral side of the body. The scutellum and membrane are fairly large, the latter is veined. The legs are thin and long. Oviposition takes place underground.

FAMILY TINGIDAE see Chapter III Nos. 38, 189, 324, 411

lace bugs

Small, delicate bugs, measuring only a few millimetres. The hemelytra are much longer and broader than the body, their venation is reticulate. The pronotum is angular and often convex. The eggs are inserted in tender plant parts.

FAMILY MIRIDAE see Chapter III Nos. 44, 93, 94, 95, 96, 137, 712, 732, 797, 812

leaf bugs

Small to medium-sized, brightly coloured bugs with 4-jointed beak and antennae; the latter are long and slender. The tarsi are 3-jointed. The eggs are inserted in tender plant tissue.

Order Homoptera

cicadas, leafhoppers, white flies, aphids, scale insects and others

The beak is attached to the hind part of the underside of the head. The wings are membranous, transparent, usually held sloping roof-like over the body. Insects of this suborder feed by sucking plant sap. Homoptera are divided into the following five suborders:

Suborder Cicadina

FAMILY FULGORIDAE = *planthoppers* see Chapter III Nos. 190, 237, 290, 293, 394
FAMILY CICADIDAE = *cicadas*
FAMILY CERCOPIDAE = *froghoppers*
FAMILY JASSIDAE = *leafhoppers* see Chapter III Nos. 191, 192, 241, 452, 667, 668
FAMILY MEMBRACIDAE = *treehoppers*

Small to medium-sized insects with a broad head and 3-jointed antennae, the last segment of which forms a thin bristle. The forewings are often more thickly chitinized than the hindwings. The hind legs are long, fitted for leaping; the tarsi are usually 3-segmented. The females have an ovipositor with which they introduce the eggs either into the soil or under the epidermis of a plant.

Suborder Psyllina

FAMILY PSYLLIDAE

jumping plant lice

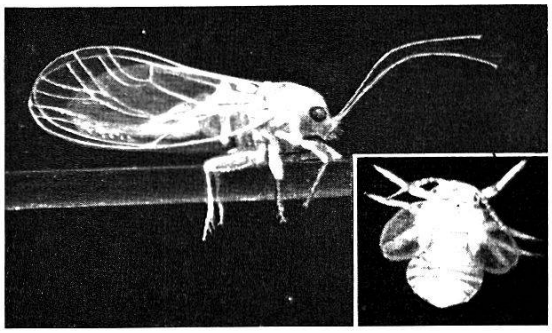


Fig. 15
(8× enlarged)

Small, frail, leaping insects, the antennae of which are long and thin. The forewings are usually chitinized. The tarsi have 2 segments. Members of this group secrete a waxy substance. The body of the larvae is flattened.

Suborder Aleyrodina

FAMILY ALEYRODIDAE

white flies

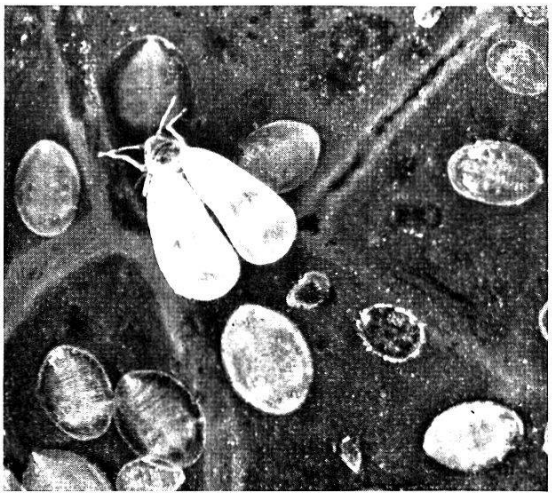


Fig. 16
(8× enlarged)

Minute, very frail Homoptera, the wings of which are covered with a whitish dust. The antennae are 7-jointed. The legs are long and thin, the tarsi have 2 segments. The larvae, which resemble scale insects, live as flat, oval, shield-like bodies on the leaves. They undergo a pupal rest before reaching the adult stage.

Suborder Aphidina

FAMILY APHIDIDAE

see Chapter III Nos. 314, 503

aphids, plant lice

Small, soft-bodied insects with 2 pairs of wings. The antennae are thread-like, 4-6-jointed. The legs are long and slender. The tarsi have 2 segments. The penultimate abdominal segment bears a pair of tubes or cornicles; these, however, do not secrete honeydew. Honeydew is a faecal excrement which contains sucrose and is expelled through the anus. The development of aphids is heterogamous, parthenogenetic generations alternating with sexual generations. Reproduction is either oviparous or may alternate between oviparous and viviparous, i.e., with

intermediate parthenogenetic generations. Heterogamy often goes parallel with a change of host plants, the whole development cycle evolving on two different species of food plants. Aphids live either singly or in colonies; they may be found either living freely on various plant parts or inside galls which are caused by their sucking, or they may occur underground on roots.

Suborder Coccina

FAMILIES MARGARODIDAE, PSEUDOCOCCIDAE

mealybugs

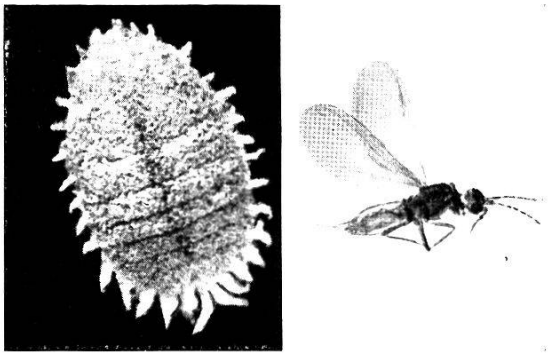


Fig. 17
(10× enlarged)

see also Chapter III Nos. 72, 271, 384, 433, 489, 819, 873

The females are broadly oval, convex, small and relatively soft-bodied, measuring only a few millimetres. The body is yellow to reddish, covered with loose, white waxy threads. There is no shield and the segmentation of the body is usually clearly visible. The mouth parts are developed into long, slender stylets. Mealybugs have usually well developed legs; they move about both in the larval and adult stages. The eggs are enclosed in a loose, woolly egg-sac. The males, considerably smaller than the females, have 2 wings; their mouth parts are vestigial. Females have 4, males 5 instars.

FAMILY LECANIIDAE (STICTOCOCCINAE)

tortoise scales

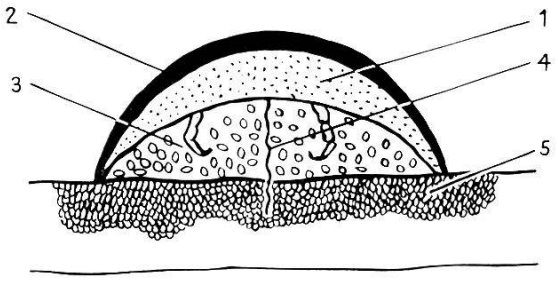


Fig. 18
1 = body, 2 = shield, 3 = eggs, 4 = mouth parts, 5 = plant tissue

see also Chapter III Nos. 20, 21, 99, 446, 447, 457, 487, 506, 596

Small lice, only a few millimetres in size, with round or oval, sometimes convex hemispherical scales. The legs are usually well developed. The mouth parts form long stylets (4). The shield (2) is formed by a chitinous thickening of the dorsal

body wall during the last sexual stage; it acts as a shelter under which the eggs (3) are laid. After oviposition the soft ventral side of the female may shrivel up altogether. By lifting the shield the whole insect can be removed and numerous small eggs become visible. Tortoise scales secrete honeydew and remain in one place once they start sucking. Parthenogenetic reproduction is frequent.

FAMILY DIASPIDIDAE
scales

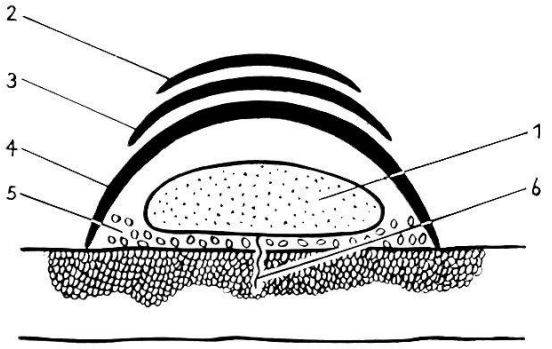


Fig. 19
1 = body, 2 = first exuvia, 3 = second exuvia, 4 = shield, 5 = eggs, 6 = mouth parts

see also Chapter III Nos. 342, 387, 448, 507, 531, 533-540, 597-600

Minute pear- or egg-shaped lice, 1-2 mm in size, flattened dorsoventrally, with very short legs and a distinctly segmented abdomen. The mouth parts are developed into fine, long stylets (6). The insects are covered with scale-like shields, formed of a waxy secretion. The females bear the first (2) and second (3) exuviae on the shield (4) which is then shed. The shield is then no longer attached to the insect, so that when the shield is removed, the pear-shaped, often yellow body remains intact. Adults remain stationary once they start sucking; only the first larval stage is mobile. The males are usually winged (only forewings), but have no beak; they also develop under a shield which is, however, smaller than that of the female. Females have 3, males 4 instars.

Order Coleoptera

beetles and weevils

Members of this order are usually free-living, heavily chitinized, varying greatly in size. The mouth parts are of the biting and chewing type. Both prothorax and metathorax are salient, exceeding the mesothorax in size. The thick and strong forewings (elytra) cover the membranous, folded hindwings and the abdomen. In some cases the elytra do not extend over the last abdominal segment or leave a small triangle (scutellum, see also No. 567 and Fig. 14) of the mesothorax visible. Adults and larvae often differ in their nutritional habits. The development is holometabolous.

FAMILY CARABIDAE
ground beetles

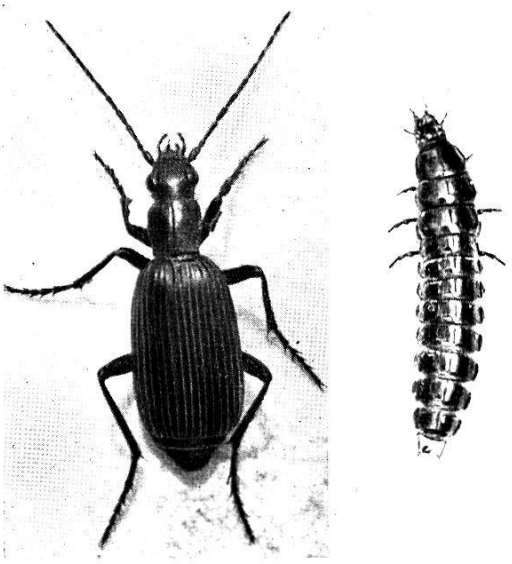


Fig. 20

Ground beetles are small to very large, dark or metallic in colour. The antennae are thin, of medium length. The slender legs have 5-segmented tarsi. In daytime the ground beetles hide under stones, foliage and the like. They roam about at night in search of other insects and invertebrates. Oviposition takes place in moist, well concealed places. The eucephalous-oligopode larvae live predaciously. Some of them feed also on seeds.

FAMILY ELATERIDAE
click beetles

see Chapter III No. 679

Flattish, spindle-shaped, slender beetles with short, serrate or comb-like antennae and thin legs. The head is often retracted into the prothorax; the latter is loosely joined to the mesothorax and ends in a sting directed posteriorly and embedded in a groove of the mesothorax. This arrangement enables click beetles to leap up when lying on the back by propping the tip of the sting against the edge of the groove, letting it then drop into the latter. The eggs are laid underground. The yellow, eucephalous-oligopode larvae, termed "wireworms", are long and cylindrical; the head is depressed. Both adults and larvae feed on plants. The wireworms live underground where they damage seeds, saplings and roots.

FAMILY BUPRESTIDAE
metallic wood borers

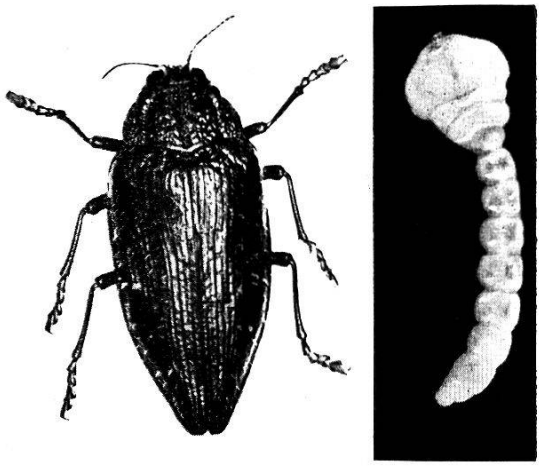


Fig. 21

Buprestids are heavily chitinized, shiny metallic, fairly depressed insects. The head is vertically withdrawn as far as the eyes into the prothorax. The antennae are

short, serrate on the inner side. There is a short, immobile pronotal sting (differing from that of Elateridae, where it is mobile). Metallic wood borers live on flowers and oviposit on the bark of various plants. The eucephalous-apode larvae live in the wood of trees or inside plant stalks. The head is strikingly large, while the abdomen is narrow and elongate. Some species of this family are serious plant pests.

FAMILY BOSTRYCHIDAE

see Chapter III No. 14

powder post beetles

Cylindrical beetles of various sizes, resembling ground beetles in their habits. The head is protected by the hood-shaped prothorax so that it is almost invisible from above; the prothorax is dented at the front end. The eggs are laid on branches and trunks. The larvae have a small, globular head and strongly resemble grubs, the first segments of their body being thickened (see also Scarabaeidae). They live in various species of trees, mining the wood.

FAMILY COCCINELLIDAE

lady-birds

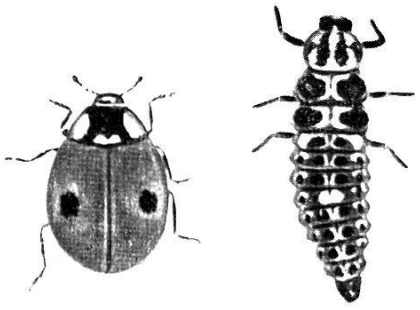


Fig. 22
(1× enlarged)

Usually small, variegated beetles, only a few millimetres long. The body is hemispherical, the head mostly covered by the prothorax. When touched the beetles secrete blood from the leg joints which has corrosive properties. Lady-birds feed on aphids and other small insects. They deposit their eggs on leaves where the free-living eucephalous-oligopode larvae are found. The larvae are often brightly coloured, the upper side of the body furnished with hairy warts or spiny, often forked appendages. They also feed on aphids. Both adults and larvae are predacious, destroying many small harmful insects. One group of Coccinellidae, however, the Epilachnidae, are herbivorous, devouring the aerial parts of various crops.

FAMILY CHRYSOMELIDAE

leaf beetles

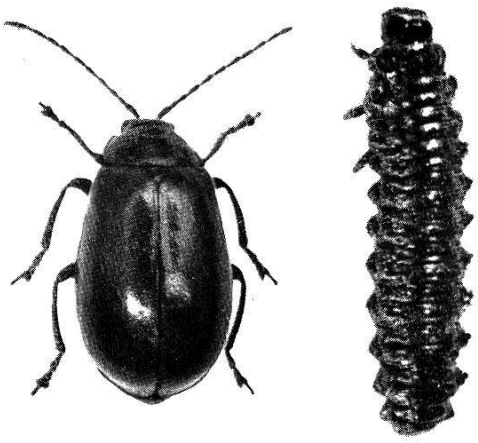


Fig. 23
(3× enlarged)

Rather small, usually metallic, oval or globular, convex beetles, mostly with a bare dorsum. Flea beetles, one group of this family, have very thick femora of the hind legs, fitted for leaping. Oviposition takes place on leaves or underground. The adults live freely on leaves or stems of their host plants. The larvae are eucephalous-oligopode; the cylindrical body, tapering towards both ends, is covered with tubercles and spines. They live either freely and gregariously on leaves, or mine in leaves or stems, or underground. They may also live inside sac-like structures made of excrement. Others, such as the small, elongate larvae of flea beetles, live underground, where they feed on roots. Chrysomelids are serious plant pests.

FAMILY CERAMBYCIDAE

see Chapter III Nos. 11, 57-59, 107, 429

longicorn beetles

Robust, medium to large-sized, fairly slender beetles, the antennae of which are sometimes more than half the length of the body and sometimes even longer than the whole body. The first antennal segment is large. The prothorax is usually narrower than the elytra. The legs are slender, the thighs often clubbed and thickened. The adults frequently are found on flowers, leaves or on those plant parts which discharge sap. Oviposition takes place on the bark or inside cracks of the bark. The larvae have creeping disks or pads instead of legs; the prothorax is broadened to a disk which surrounds the head. The larvae of longicorn beetles usually live inside live or dead wood, where they mine long, serpentine galleries, filled with frass. They are important plant pests.

FAMILY CURCULIONIDAE

see Chapter III Nos. 118, 388, 389, 567, 846

weevils or snout beetles

Small or large beetles of various colours. The head is more or less extended to form a beak, bearing the jaws at the tip. The antennae are either straight or bent at the base. In the latter case, the basal segment has a shaft-like prolongation, and the tip of the flagellum is usually clubbed. Weevils feed on various parts of a plant and lay their eggs inside fruits, buds, leaf stalks, shoots, steams or underground. The larvae are maggot-like, blind, curved ventrally, with no legs or only leg rudiments. Weevils are important plant pests.

FAMILY IPIDAE

bark beetles

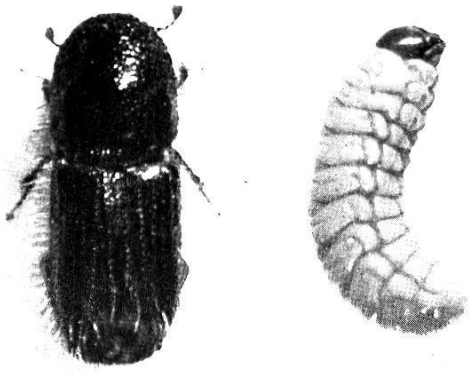


Fig. 24
(8× enlarged)

Minute, dark brown to reddish-brown beetles, measuring only a few millimetres. The head is narrower than the prothorax. The beak is indistinct, very short and broad. The antennae are also short and the clubs ringed. When ovipositing, the females tunnel partly or completely into a plant. Bark beetles take great care of their brood. The females carve special niches branching out from the main tunnel, whence the larvae go tunnelling into the plant tissue. The arrangement of galleries thus produced is characteristic for the respective species. Bark beetles usually attack only sickly plants or those which are not thriving. Their presence or absence may serve as an indication of the state of health of a plant.

FAMILY SCARABAEIDAE see Chapter III Nos. 104, 117, 264, 513, 565, 678

lamellicorn beetles

Medium to large-sized, convex and thickly chitinized beetles with bent antennae, the tips of which form a lamellate club. The fore legs are usually broadened, fitted for digging. The tarsi are 5-jointed (May beetles, June bugs, Rhinoceros beetles). The eggs are deposited underground. The larvae are so-called "white grubs"; they are blind, fleshy, curved ventrally and therefore always lying on their sides. The legs are well developed and the abdomen is inflated. Lamellicorn beetles are much dreaded as plant pests. The adults feed on leaves, buds, etc., while the larvae destroy the roots.

Order Hymenoptera

saw-flies, wasps, bees, ants

Members of this order are small to medium-sized. The mandibles are formed for biting, the maxillae for lapping and chewing; in some species the maxillae are joined with the labium to form an elongate apparatus, fitted for lapping and sucking. There are 4 membranous, scarcely veined wings. The females either have a well developed ovipositor or this organ is converted into a sting and a poison gland. The larvae usually have the shape of maggots, sometimes they resemble caterpillars (saw-flies). They spin a cocoon, inside which the pupa is enclosed. Several Hymenoptera are social insects forming colonies (bees). Their development is holometabolous.

FAMILY TENTHREDINIDAE

saw-flies

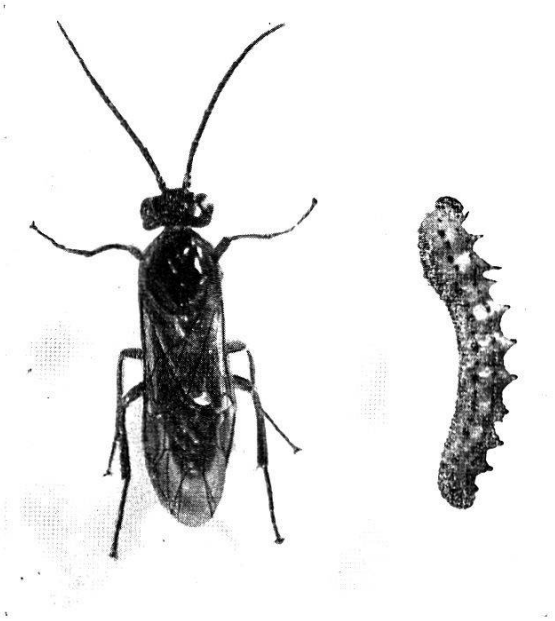


Fig. 25
(1× enlarged)

Saw-flies are often variegated, medium-sized insects with a relatively large head, which has straight antennae of 3 or more segments, often serrate or comb-like in the male. The abdomen is joined broadly to the thorax. The eggs are laid on or in plants. The larvae feed on various parts of a plant. They resemble caterpillars, but are characterized by 3 pairs of thoracic legs, and one or 6-8 pairs of abdominal legs, thus a total of usually 18-22 legs. Lepidopterous caterpillars have 2-5 pairs of abdominal legs in addition to 3 thoracic pairs, thus a total of 10-16 legs.

FAMILY SIRICIDAE

horntails

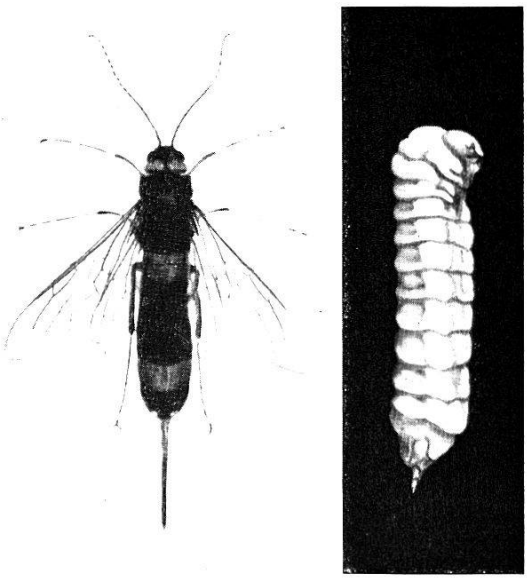


Fig. 26

Strikingly coloured, medium to large-sized wasps with 10-30-jointed antennae. The mouth-parts are fitted for biting and chewing. The females have a very long ovipositor which may be either almost concealed or protuberant. The abdomen is joined broadly to the thorax. The ovipositor serves to insert the eggs deep into herbaceous or ligneous plants. The emerging larvae are soft and whitish; they have 3 pairs of thoracic legs but no abdominal legs. The last abdominal segment extends into a spear-shaped prolongation. The larvae of horntails often cause severe damage in timber.

FAMILY CYNIPIDAE

gall wasps

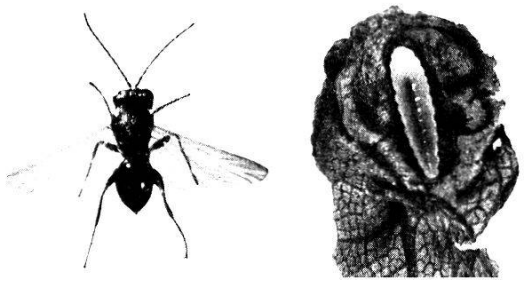


Fig. 27
(1.5× enlarged)

Small, frail wasps, the head of which bears 12 to 16-segmented antennae. The body is constricted to form a waist, typical of wasps. The abdomen is compressed laterally and has an ovipositor. Gall wasps pierce the plant tissue, into which they deposit their eggs. The plant reacts with abnormal growth, producing a gall round the larval cell in which the larva develops and pupates. The larvae are footless and have an indistinct head. They are of little practical importance in agriculture.

FAMILY ICHNEUMONIDAE

ichneumon flies

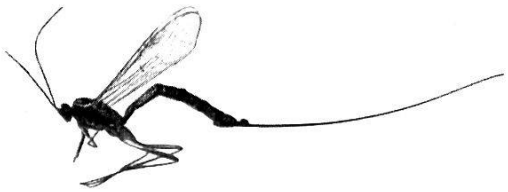


Fig. 28

These are small to medium-sized, delicate wasps. The thorax is formed of 3 thoracic and the first abdominal segments. The abdomen is attached to the thorax either by a short or a long pedicel. The wings are densely veined. The eggs may be laid on or near the host; usually they are introduced into the host by means of an ovipositor. The larvae have an indistinct head, but the mandibles are conspicuous. Ichneumon flies parasitize the body of other insects; they play an important part in the biological control of plant pests.

FAMILY VESPIDAE

see Chapter III No. 526

wasps

Wasps have their mouth parts developed for biting. The wings are folded lengthwise when at rest. The abdomen of the female is armed with a poisonous sting and gland. Wasps may have either solitary habits or live in colonies. They build their nests from clay or chewed plant substance which they glue together with saliva. They feed on small insects and plant juice, the secretion of which they stimulate by gnawing the bark. The larvae are dark-headed, footless and maggot-like. Wasps gnawing fruits are of only little significance in agriculture.

FAMILY APIDAE

bees

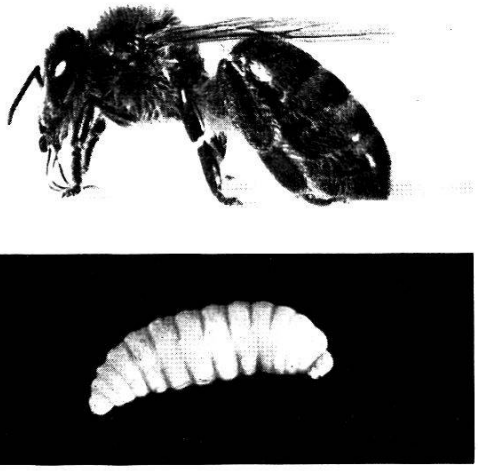


Fig. 29
(1× enlarged)

Usually medium-sized, more or less hirsute insects, the mouth parts of which are developed for biting and sucking. The hind legs of the females are usually densely covered with hairs, or broadened and grooved, so that they can be used for gathering food. The abdomen is attached to the thorax by a short pedicel. The female is armed with a poisonous sting. Bees gather pollen and nectar for the nutrition of their maggot-like larvae. Some species (honey bees) have social habits, while others live solitarily. Their nests are formed of cells built of earth particles or wax; they are found in the ground, in walls or in hollow trees. Bees play an important part in the cross-pollination of flowers and in producing honey.

FAMILY FORMICIDAE

see page 465, Fig. 66

ants

Order Lepidoptera

butterflies and moths

Very small to large insects with 4 wings, covered with scales. The body and the legs are also covered with scales. The antennae are either brush-like or thread-like. The mouth parts are joined to form a spiral sucking tube. The mouth parts of caterpillars are of the biting type. Caterpillars have 3 pairs of thoracic legs, and usually 5 pairs of non-segmented abdominal legs—the so-called prolegs—one pair fixed to each of the 6th, 7th, 8th, 9th and 12th segments. The prolegs are armed at the extremity with numerous chitinous hooks (or "crochets"). When these hooks are arranged in a semi-circle, they are called "penellipse"; when they form a complete circle, they are

called "uni- or multiserial circle". While in most caterpillars of moths or *Microlepidoptera* the hooks are of the latter type, forming a distinctive characteristic of this group, *Macrolepidoptera* usually have them placed in a semi-circle.

Larvae differ fundamentally from adults in their feeding and behaviour; their development is holometabolous.

A. Microlepidoptera

FAMILY TINEIDAE

moths (tineids)

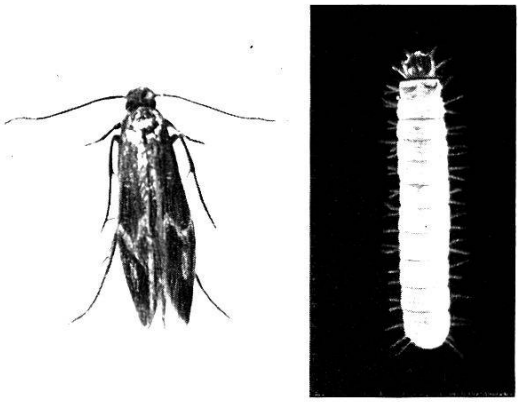


Fig. 30
(1× enlarged)

Usually small insects, measuring a few millimetres only. The head is clothed with erect hairs. The antennae are shorter than the forewings; when at rest the moths lay them back against the wings. The male bears an anal tuft of hairs, while the female has a prominent ovipositor. The caterpillars have a strong head capsule and thoracic shield; they are either hairless or bear scattered hairs or bristles and small tubercles. They live either in webs, cases, or tubes, and eat leaves.

FAMILY PYRALIDIDAE

see Chapter III Nos. 215, 273, 438, 614

pyralids or snout moths

These are medium-sized moths with a slender body and long, thin legs. The forewings are long and usually narrow, while the hindwings are broad with a pinnate margin. The wings are held either horizontally or like a sloping roof over the body. The palpi vary greatly in length. Pyralids deposit their eggs on stems, leaves, buds and fruits of various plants. The caterpillars have a strikingly strong head capsule and thoracic shield. The body is usually naked, sometimes it has a few scattered hairs or bristles, implanted in tubercles which are often dark. The caterpillars feed either on or inside various parts of a plant. Many pyralid species are dangerous plant pests.

FAMILY TORTRICIDAE

leaf rollers

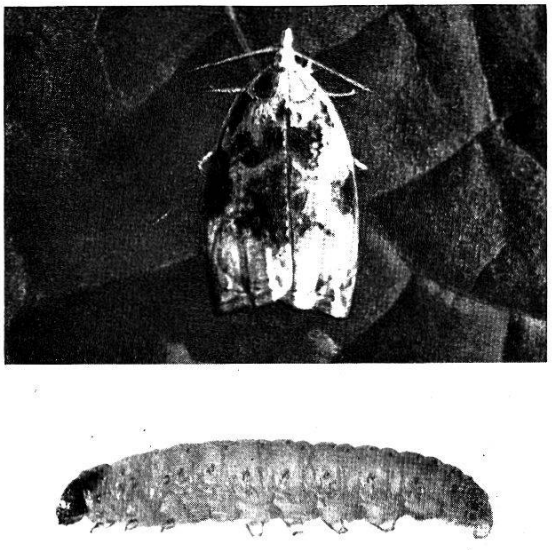


Fig. 31
(½ enlarged)

Small to moderate-sized moths with a stout body. The head is either smooth or covered with woolly scales. The forewings are often curved at the costal margin and folded near the base. The outer margin is either oblique, arched, straight or undulating. The apex is either rounded off, terminated in a point or sickle-shaped. The hindwings may be broad, trapezoid or triangular. When at rest the wings are held either horizontally or roof-like. The thighs of the hind legs are armed with two pairs of strong spurs. The usually flat, shield-like eggs are fixed on various parts of a plant. The caterpillars may be naked or sparsely clothed with hairs or bristles, which are inserted in small tubercles. The head capsule and thoracic shield are usually reddish-brown to black. The caterpillars feed on or inside various parts of a plant. Many representatives of this family are dangerous plant pests.

FAMILY LYONETIIDAE

ribbed cocoon makers

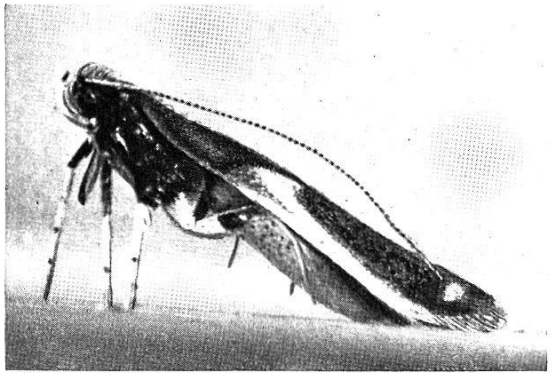


Fig. 32
(4.5× enlarged)

Small moths which may be found in daytime in shady places with the thorax held erect and the wings folded to a tent. The head is covered with smooth scales and bears an erect hair tuft on the front. The antennae are almost as long as the forewings, which are long and narrow. The eggs are deposited on leaves in which the 16-legged caterpillars mine between the upper and lower epidermis, after which they pupate on the underside in a net hung with silky threads between the leaves (see No. 26, page 75).

FAMILY HYPONOMEUTIDAE

see Chapter III No. 560

hyponomeutid moths

Medium-sized moths, the head of which is clothed with hairs. The forewings are long and narrow, almost linear, while the hindwings are broad. The eggs are deposited on various parts of a plant. The head capsule and thoracic shield of the caterpillars may have any shade between light and dark. The caterpillars have 16 legs; they live gregariously inside loose webs fixed to various plant parts. Newly hatched caterpillars may also mine into the plant tissue.

FAMILY COLEOPHORIDAE

casebearers

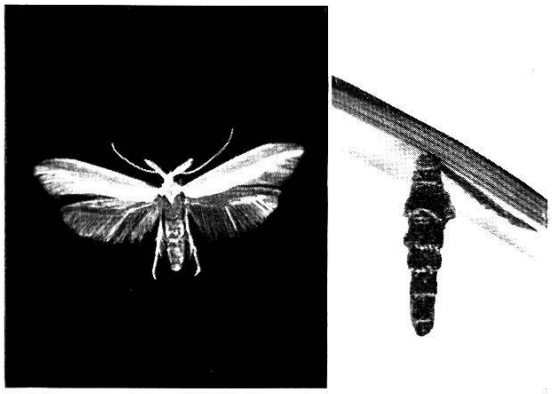


Fig. 33

Small to medium-sized moths, the head of which is covered with flat scales. The antennae are moderate in length and have a hair tuft at their base. Both they and the palpi are usually held extended forward in repose. The forewings are stretched out, while the hindwings are narrow, lance-shaped. The abdomen is relatively long. The male has a thin anal tuft. Oviposition takes place on leaves and stems. The caterpillars have 16 legs. The terminal segment is densely clothed with erect bristles. From leaf particles or other plant material such as bark, the caterpillars build a case in which they hide.

B. Macrolepidoptera

FAMILY GEOMETRIDAE

measuring worms, loopers

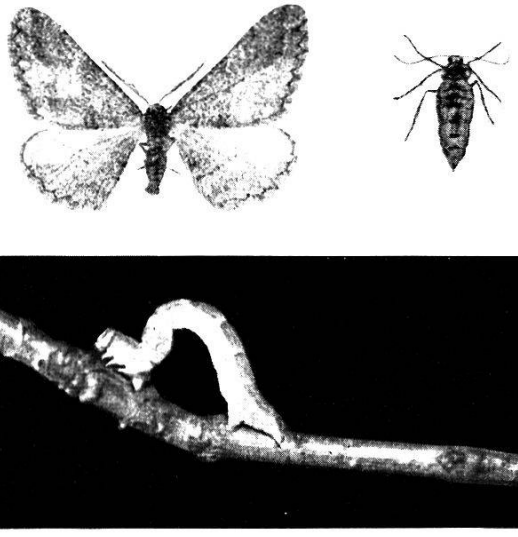


Fig. 34

Usually slender moths of moderate size with thin legs and brush-like antennae; those of the males are often comb-like. All four wings are almost similar in shape,

spread out horizontally in repose. In many species the females have vestigial, rudimentary wings only. The caterpillars have three pairs of legs near the head and three pairs of thicker prolegs behind the middle. When they crawl, the middle portion of the body forms a distinct loop each time the functional prolegs are carried forward. The caterpillars live externally on their host plants.

FAMILY NOCTUIDAE

owlet moths

see Chapter III Nos. 177, 220, 231, 521, 522

Medium-sized moths, which are usually on the wing at night. The body is densely hirsute and the abdomen blunt. The antennae are brush-like. The wings, when at rest, are folded to a steep roof over the body. The forewings are long, triangular, with an oblique seam; they are usually dull in colour, marked with a kidney- or ring-shaped spot and undulating crossbands. Noctuids are very active at night, avidly visiting flowers. The eggs are laid on various parts of a plant. The caterpillars are naked; before the first two moults they often have 12-14 legs, while at the later stages they have 16. They first live gregariously, becoming solitary later on. In daytime they hide underground, crawling out at night to feed on practically all plant parts. When irritated they curl up.

FAMILY LASIOCAMPIDAE

tent-caterpillar moths

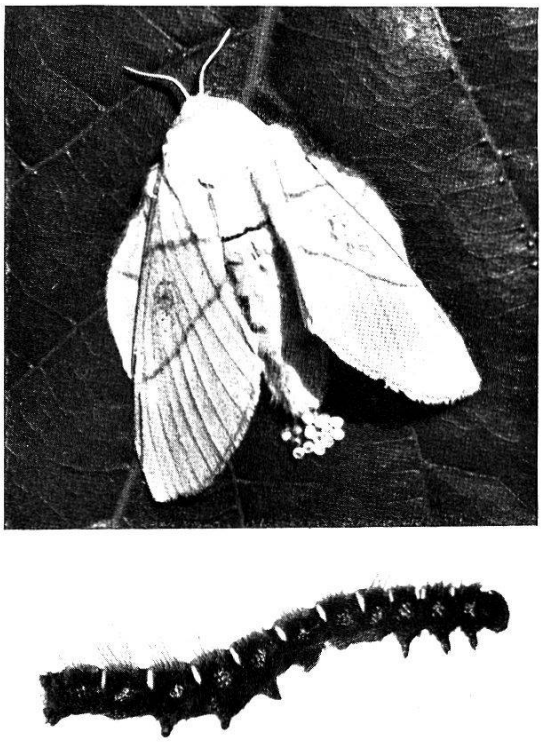


Fig. 35

Medium- to large-sized butterflies, the stout body of which is usually densely clothed with hairs. The antennae are short and comb-like. The wings, when at rest, are held like a steep roof over the body. The forewings are broad, triangular, distinctly pointed. The females lay their eggs on various parts of a plant. The caterpillars have 16 legs. They are densely clothed with soft hairs.

FAMILY LYMANTRIIDAE

tussock moths

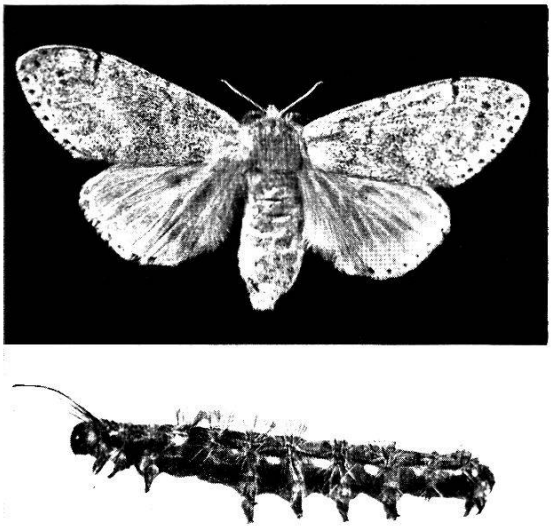


Fig. 36

Moths of moderate size with a plump and usually hirsute body. The females of some species have no wings. The eggs are laid on various parts of a plant. The caterpillars have 16 legs. The first abdominal segments are armed with short hair tufts, the contact of which causes severe irritation (urticaria) on the human skin.

FAMILY ARCTIIDAE

tiger moths

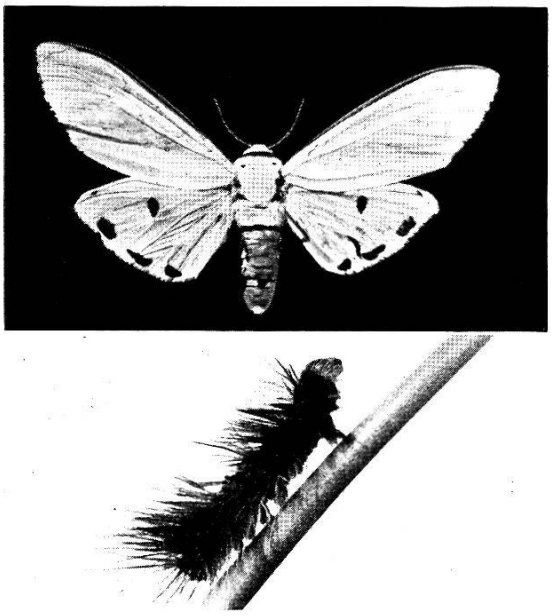


Fig. 37

Strong, medium-sized moths of various colours. The forewings are triangular, while the hindwings are broad and rounded off. When at rest the wings are folded to a roof. The eggs are deposited on various parts of a plant. The caterpillars are densely clothed with hairs; they feed on leaves and pupate inside a loose web.

FAMILY LIMACODIDAE

slug-caterpillar moths

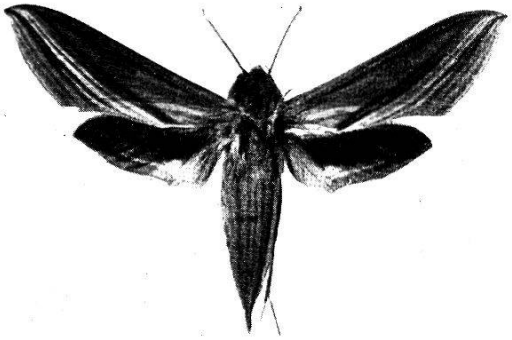
Fig. 38

see Chapter III Nos. 29, 30, 736

Medium-sized butterflies of a great variety of colours. The antennae are long and thread-like. When at rest the wings form a fairly flat roof over the body. Oviposition takes place on the plants. The caterpillars resemble wood-lice or slugs; they are short, fairly convex and bear venomous setae which cause severe skin irritation.

FAMILY SPHINGIDAE

hawk moths



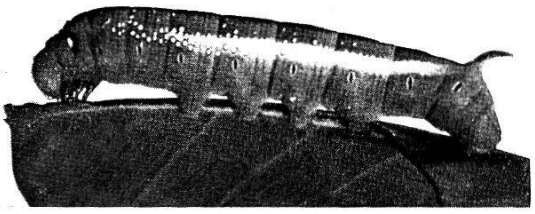


Fig. 39
(⅓ reduced)

Medium- to large-sized moths with a stout body tapering towards the rear end. The wings form a steep roof, fore- and hindwings varying greatly in size. The forewings are long and relatively pointed. Hawk moths are excellent fliers. They have a very long beak (up to 80 mm long). The eggs are laid on various parts of a plant where the caterpillars feed voraciously. They are fleshy, hairless, often vividly coloured and bear a conspicuous horn on the 11th segment.

FAMILY PAPILIONIDAE

see Chapter III No. 496

swallowtail butterflies

Medium- to large-sized butterflies, often beautifully coloured. The body is slender, the antennae are long and clubbed at the tip. When at rest both fore- and hindwings are held erect, the upper sides against each other. The eggs are deposited on various parts of a plant. The caterpillars are cylindrical, hairless and fleshy; the pupae are fixed by a thread to the plant.

Order Diptera

comprising the suborders Orthorrhapha: *Straight-seamed flies*
Cyclorrhapha: *Circular-seamed flies*

Diptera have sucking or piercing mouth parts and membranous forewings; the hindwings are reduced to small knobs, termed halteres. Only the footless larvae are injurious; they feed on plant tissue. The development of Diptera is holometabolous.

Suborder Orthorrhapha

FAMILY CECIDOMYIDAE

gall midges (gall gnats)

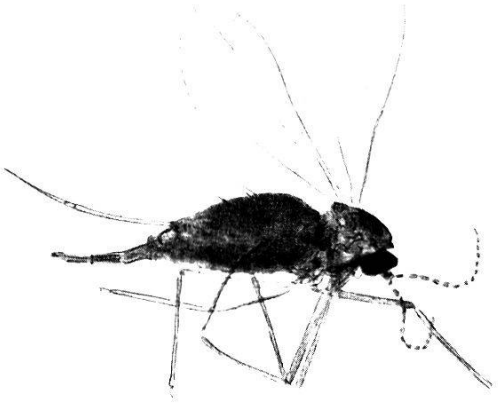


Fig. 40
(6× enlarged)

These are tiny insects with usually large, scarcely veined wings. The antennae have many segments; the legs are long, the thighs have no spur. The abdomen of the female is extended into an ovipositor. The larvae are usually yellowish-orange to reddish-orange; their antennae are short, 2-jointed. They usually live inside the plants, where their feeding causes the formation of galls; others are predators of such insects as aphids.

FAMILY TIPULIDAE

crane flies

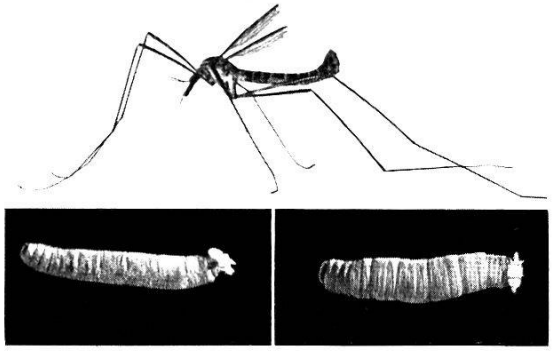


Fig. 41
(⅓ reduced)

Large insects with a short beak, and no stylets. The legs are extremely long. The larvae are hemicephalous and have very strong jaws. The body is elongate, cylindrical, with a blunt abdominal end. The latter bears two fleshy warts surrounding two large spiracles. Crane fly larvae live underground, feeding on roots or on decaying wood.

Suborder Cyclorrhapha

FAMILY CHLOROPIDAE

frit flies

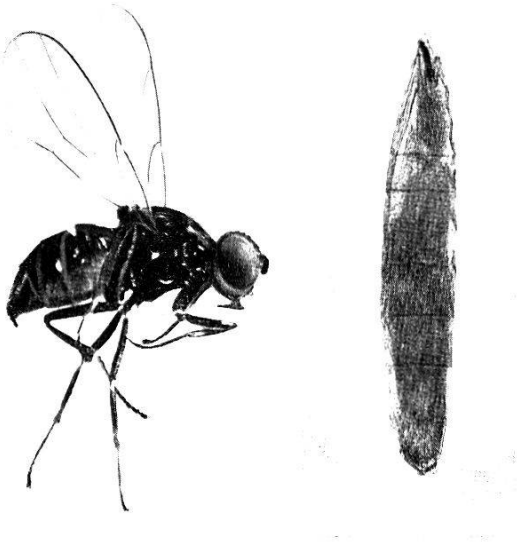


Fig. 42
(8× enlarged)

Minute flies, usually of metallic coloration, measuring only a few millimetres. The wings are relatively short. The thorax is often decorated with bands. The eggs are laid on the plants into which the white, footless maggots penetrate. Chloropidae have a preference for Graminae.

FAMILY TRYPETIDAE

see Chapter III Nos. 523, 562

fruit flies

Small to medium-sized, often brightly coloured flies, the abdomen of which consists of 5 segments. The wings, usually broad and fan-like, often bear dark markings. The female has a distinct ovipositor with which it inserts the eggs into fruits and other soft plant tissue. The white, footless maggots, after mining the plant tissue, pupate either inside the mines or in the ground.

FAMILY AGROMYZIDAE

leaf miners

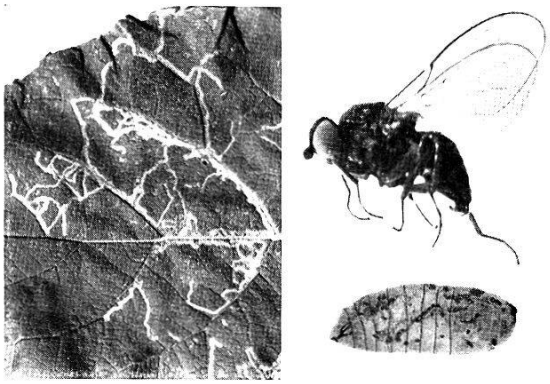


Fig. 43
(5× enlarged)

Tiny, usually dark coloured flies, the abdomen of which consists of 6 rings. The female has a distinct ovipositor with which it deposits its eggs on various parts of a plant. The white to creamy-white, footless maggots mine inside the leaves, stems and other parts of a plant, often causing the formation of galls.

ARACHNIDA

Order Acarina

Suborder Trombidiformes

mites

Arachnids have the head and thorax joined to the so-called cephalothorax. The abdomen is usually unsegmented and together with the cephalothorax, forms an oval body. The mouth parts are fitted either for biting and sawing, or for sucking or piercing. The development of mites comprises several instars. The 6-legged larvae go through 2 nymphal stages before they become sexually mature adults. Respiration is done either through spiracles and tracheae or through the cuticula. Reproduction is usually sexual, either oviparous or viviparous.

FAMILY TETRANYCHIDAE

spider mites

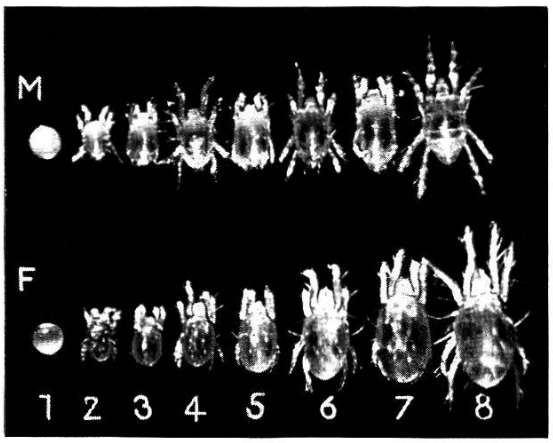


Fig. 44
(25× enlarged)

M = male; F = female; 1 = egg; 2 = larva; 3 = nymphochrysalis; 4 = protonymph; 5 = deutochrysalis; 6 = deutonymph; 7 = teleiochrysalis; 8 = adult.

Minute, oval mites with a soft cuticula and rows of bristles on the back. There are 1-2 eyes on each side of the cephalothorax; this latter is separated from the abdomen by a distinct furrow. The legs are relatively long and hirsute. The mites insert their piercing-sucking mouth parts into the plant tissue, and feed on cell sap. Development: the 6-legged larva emerges from the egg, goes through various quiescent stages (nymphochrysalis, deutochrysalis, teleiochrysalis) to become an 8-legged nymph and eventually an adult.

FAMILY ERIOPHYIDAE

gall mites

Fig. 45
(40× enlarged)

Minute, worm-like mites with an elongate abdomen, traversely grooved. The body tapers slightly at both ends. The mouth parts form a beak which is directed downwards. Only 2 pairs of legs are developed, the two posterior pairs being modified into bristles. Attacks of gall mites cause gall formation and deformities of the plant.

MYRIAPODA

centipedes and millipedes

Fig. 46

Elongate, heavily chitinized arthropods. The body of the adult consists of numerous segments or rings. The head capsule is distinctly separate and always bears a pair of segmented, thread-like or sometimes club-shaped antennae. Each segment of the body has 1 or 2 pairs of short, cylindrical legs. Respiration is done through tracheae; the spiracles are arranged laterally on the segments. Irritation causes myriapods to curl up ventrally.

Myriapods feed on decaying vegetable or animal matter and are therefore chiefly found in humus. They also sometimes gnaw living plant tissue such as germinating seeds or young roots.

NEMATHELMINTHES

roundworms

The name roundworm indicates the external appearance of these organisms. Their body is unsegmented and ungrooved. The body cavity immediately surrounds the intestinal canal; this latter ends in an anal aperture.

Order Nematoda

Nematodes are represented by many groups of thread-like worms which live either as endo- or as ectoparasites on plants. The body is covered with a resistant cuticula.

FAMILY ANGUILLULIDAE

eelworms

Small worms measuring only a few millimetres and living in moist soil or in plant tissue. Usually both males and females are present. The eggs are relatively large. A characteristic feature of these worms is a sting in the mouth cavity which is fitted for piercing and can be extended or withdrawn. The tip of the sting tapers to a sharp point. It is connected with a swelling at the base, grooved to a channel opening in front, and connected at the base with the digestive canal. During food uptake the cell sap is pumped by the muscular swelling through this channel. Economic damage caused by light attacks of eelworms is often overlooked or underestimated. Heavy infestation results in considerable loss of yield, influenced also by temperature, humidity, variety and general disposition of a crop, soil and local conditions.

Plants rarely die from nematode attack, but they usually become misshapen, weakened, dwarfed, so that they are very susceptible to other pests and diseases, injuries caused by worms giving access to fungus or bacterial organisms. (It is well known that virus diseases on plants can be transmitted by plant nematodes.) Damage caused by eelworm infestation usually occurs gradually as a consequence of insufficient crop rotation. The survival of the pest in the soil leads to constant infestation of new plant material brought to the same place.

A short précis of some of the most important plant parasitic nematodes is given below.

Leaf nematodes

(Aphelenchoides)

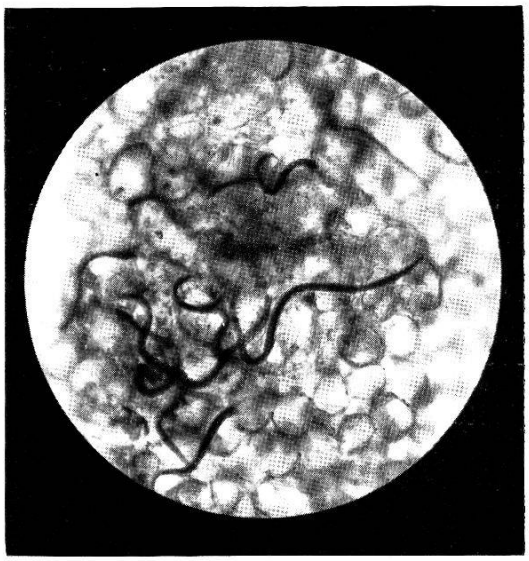


Fig. 47
(30× enlarged)

Minute, colourless endoparasitic nematodes which live mainly in the parenchymatous tissue of the leaves. They move during periods of high humidity (rain), penetrate through the stomata into the leaves, where they feed on the cell content, their sting piercing the cell walls. Their attack causes shrivelling, discoloration and withering of the leaves. The main leaf veins limit their spreading so that the withered portions are often sharply separated from uninjured parts of a leaf. Plant nematodes are capable of surviving for a long time inside withered plant parts whence they may be spread with seeds and seedlings.

Stem nematodes

see Fig. 47

(Ditylenchus)

From the soil these nematodes invade the plants in which they multiply, chiefly in the stems and leaves, causing growth disturbance such as thickened and shortened internodes, distorted stems and leaves. Secondary fungus and bacterial infection leads to partial or total rotting of plants.

Root knot nematodes

(Meloidogyne)

Fig. 48
(6× enlarged)

The presence of these nematodes usually shows in round or elongate-oval knots of various sizes on plant roots. Inside these knots female eelworms, their larvae and eggs are found. The fully grown females are swollen to pear- or lemon-

shaped bodies, while the males and the early larval stages preserve their worm-like shape. Rotting and decaying knots release the eelworms and their eggs into the soil, where they infest new plants, the larvae penetrating the roots. Secretion of salivary fluid causes hypertrophy of the plant cells, thus producing the characteristic knots. Symptoms of attack of root knot nematodes are: flaccid and wilting leaves, growth inhibition, abortive setting and precocious ripening of fruits, abnormally dense formation of secondary roots.

Root cyst nematodes

(Heterodera)

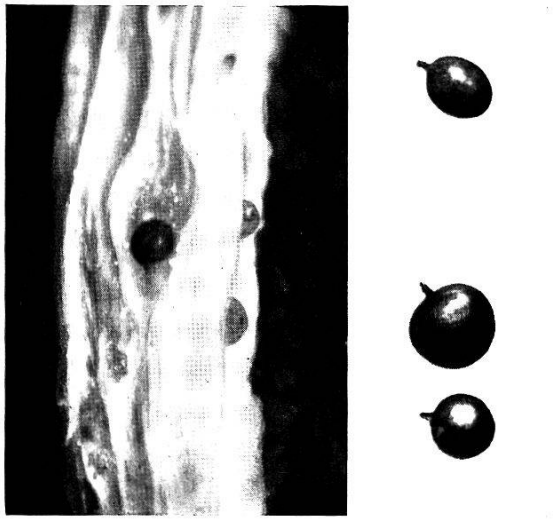


Fig. 49
(15× enlarged)

Infestation with root cyst nematodes can be recognized by the presence of small, white, globular bodies on the surface of plant roots. When dead, these bodies are brown cysts containing masses of eggs. Detached from the roots, these cysts lie in the soil, harbouring eggs which may remain viable for a long period (several months or even years). The thread-like larvae penetrate the roots. After the second moulting the body becomes bottle-shaped. During further development the female swells to a globular body, while the male becomes thread-like. After mating the females leave the plant tissue and remain clinging to the surface of the roots. Infested plants show reluctant growth, flaccid and wilting foliage, and abnormal formation of secondary roots, leading to serious loss of yield.

Ectoparasitic root nematodes

(various genera)

Fig. 50
(15× enlarged)

These are widespread nematodes which attack and damage the surface of the roots, piercing the plant tissue and sucking the cell sap. Injuries caused by them

give access to rot-causing fungus or bacterial organisms which may produce root rot, reluctant growth, dwarfing and reduction of yield. Symptoms of soil exhaustion may occur, similar to those caused by insufficient crop rotation, especially on soil under cultivation for a long time. In such soils mixed populations of several nematode species are often found which may be characteristic for the particular crop. These nematodes are thread-like, their length varies between 0.5 mm and 4 mm according to the species.

In soil analyses or rotting plant roots a great number of saprobous, non-parasitic nematodes, belonging to the normal soil fauna, are always present. They can be distinguished from injurious species by the absence of a sting. Among the species with a sting, however, there are also some which do not seem to be harmful to plants. It is in any case advisable to have species with a sting examined and identified by a specialist.