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Introduction

Like all living beings, the honeybee is subject to attack at all stages of its development by various enemies acting either directly as predators, or indirectly, by disturbing the life of the colony in various ways. The most important of these enemies are those that destroy the combs, the stores, the hive itself and some predators that take foraging worker bees as they leave the hive, or those that behave as true parasites by raising their offspring in the bodies of bees.

In reality, as their action is limited in time and in space, these enemies do not cause much damage except under exceptional circumstances. Even the very idea of their harmfulness cannot be dissociated from their usefulness from the point of view of biological equilibrium. This equilibrium stems from the competition of animals and plants in the struggle for life and the description of being harmful or useful, attributed to one or the other, is often only a reflection of a superficial, subjective and circumstantial notion.

The enemies of bees can be classified as parasites, predators, disturbers, or commensals, depending on the nature of their damage and their interdependence with bees. This apparently practical differentiation, based on the most obvious facts, is in reality not completely satisfactory as the same enemy can often behave in different ways and thus justify its inclusion in different groups. Accordingly, a zoological classification scheme has been used and the sections designated at the level of orders. Apart from the mites *Acarapis woodi* and *Varroa jacobsoni* and fungal infections, which are discussed in separate chapters, we shall deal with the most common enemies of the managed honeybee, describe their harmful effects and give a clear indication of the means of protecting the hive and hive products.

Arthropods: Arachnids

Spiders

Spiders are all predatory and basically feed on insects (Guertsch, 1949; Foelix, 1982), of which the honeybee is only one prey amongst others. Spiders catch their prey in different ways. Some seek their prey actively whilst others lay in wait, camouflaged on flowers, to catch visiting insects such as flies, bees or Coleoptera. Most spiders spin webs which are sticky traps for flying or crawling insects. Some species of large spiders of the Theridiidae family (combfooted spiders) are real or potential enemies of the honeybee. These spiders spin irregular webs on which they hang upside down (Kaston, 1978). Several species of the *Latrodectus* genus (black widow spiders), which are poisonous (Rayment, 1917; Botha, 1970; Smith, 1960), are especially numerous near feral colonies and live under managed hives, in the spaces between the roofs and cover boards and especially in narrow passages between hives.

Apart from the genus *Latrodectus*, Toumanoff (1939) describes other species belonging to the closely related genera *Theridion* and *Achearanea* (family of Theridiidae) as well as spiders of the *Linyphia* type (sheetweb spiders - family of Linyphiidae) as predators of bees. However, none of these species are of major importance.

Langstroth believed that spiders were not necessarily harmful to bees and that if they had free access to the combs, they could contribute to colony defence by controlling damaging moths (Root, 1966). The familiar domestic spider, *Achaearamea tepidariorum,* spins its web in all ill-kept places including honey depots and apicultural workshops and may thus, occasionally, capture bees and feed on them.

The most damaging enemies of bees amongst the spiders are the "orb weavers" *Aranaeus quadratus, A. diadematus* and *A. marmoraeus* of the Araneidae family which may become particularly numerous in years of drought (Toumanoff, 1939; Borchert, 1974). The "crab spiders" (Thomisidae family, Fig. 1) are also fearsome enemies of bees. They do not spin webs to capture their prey but lie in wait on or near flowers.

Usually no control measures are necessary against spiders.

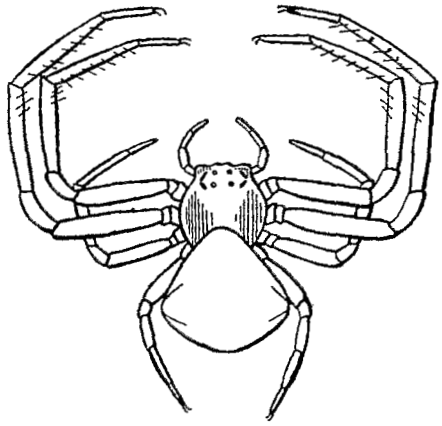

Fig. 1. *Thomisius onustus* after Toumanoff (1939).

Acari: Mites

In healthy hives, but especially in weak or diseased hives with diminished defences, a variety of arachnids can be found, belonging to three groups; the Parasitidae, Thrombididae and Sarcoptidae. Among this varied arachnid fauna are some species of free-living mites that are harmless to bees. Hives are not the usual habitat for them but they find suitable food and developmental conditions within. Some species of Tyroglyphidae and Glyciphagidae are found especially in weak colonies and when a massive invasion of these mites occurs they become harmful as they devour the pollen supplies, but in general they are not pathogenic for bees. They are easily distinguished from *Acarapis* spp. because of their larger size and oblong bodies. Within the species of Tyroglyphae, *Tyroglyphus farinae*, the flour mite and *T. longior* are found mainly in pollen stores (Borchert, 1974). The population development of all these mites is favoured by the high levels of humidity within colonies. *Glyciphagus domesticus*, the domestic mite (Fig. 2), is found relatively often in hives but mostly goes unnoticed because of its small size. Abnormally large populations can completely destroy pollen supplies in the combs.

To avoid infestation, combs containing pollen stored outside the hives are best kept under dry, cool conditions. Measures similar to those to protect stored combs against wax moth damage, should also be undertaken.

In the Tarsonemidae family, apart from the damaging tracheal mite, *Acarapis woodi*, there are some other species that live only on the body surface of the bee, apparently harmlessly: (i) *Acarapis externus* is found on the neck; (ii) *Acarapis dorsalis* on the back; and (iii) *Acarapis vagans* is found anywhere on the body (Brizard and Albisetti, 1977).

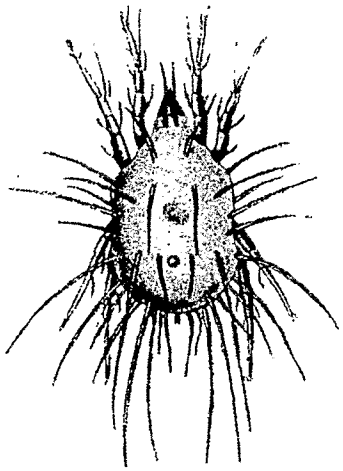

Fig. 2. *Glyciphagus domesticus* after Borchert (1970).

Pediculoides ventricosus (Fig. 3) is one of the mites harmful to bees. The female is ovoviviparous and can give birth to 300 young which often attach themselves to the same host. This parasite can be seen on uncapped and capped brood, almost always in small or weakened colonies.

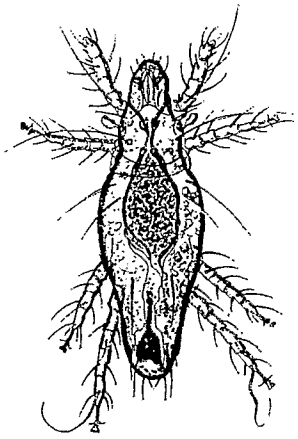

Fig. 3. *Pediculoides ventricosus* (non gravid female) after Toumanoff (1938).

Arthropods: Insects

Lepidoptera

Lepidoptera are insects characterised by the possession of four wings which are nearly always completely covered with scales. These scales impart the distinctive patterns and colours to the wings. Since the mouth parts of the adults are specialised for feeding on the nectars of flowers and other liquids, they are considered as harmless to bees. By contrast, Lepidopterous larvae (caterpillars) have masticatory mouthparts and they feed primarily on plants. They have "silk" secreting glands needed to spin the cocoon which encloses the developing pupa.

The Lepidoptera are generally divided into the Rhopalocera and Heterocera. The Rhopalocera or butterflies have a thin, fragile and elongated body and their large, broad wings characteristically

assume a vertical position at rest. Their long thin antennae are club-shaped and their posterior wings are hairless. The Heterocera or moths, have a broad and solid body, short, thick, prismatic antennae and unequal wings; the anterior wing being lengthened and narrow, the posterior wing rather rounded and hairy.

The Rhopalocera are not harmful to bees. The Sphingidae family belonging to the second group includes the species *Acherontia atropos*, the deathhead moth, a notorious enemy of the bee. But it is within the Microlepidoptera and the family Pyralidae that insects are to be found which cause the greatest damage to hives: *Galleria mellonella* L. and *Achroea grisella* (Toumanoff, 1939).

The greater wax moth, *Galleria mellonella*

In Europe and the United States, *Galleria mellonella* is reared commercially for its larvae and it is considered by some as a useful insect. The larvae are used as bait for fish and also for studies in physiology, toxicology and pathology. They may also be used as hosts for the propagation of Dipteran and Hymenopteran parasites (Morse and Nowogrodski, 1990). For beekeepers world wide, the greater wax moth is the most important pest because of the serious losses it can inflict (Smith, 1960; Singh, 1962). They destroy a large number of combs every year, attack the wax foundation and can reduce stored combs and weak colonies to a pile of debris. Wax moths only cause considerable damage in apiaries if the colonies they attack are incapable of repelling them. The susceptibility of the colony to attack may be due to several causes: malnutrition, disease, loss of the queen or large scale mortality of the worker bees due to poisoning by pesticides. Wax moths may also be implicated in the spread of contagious diseases, especially foulbrood, by consuming contaminated combs.

Geographical distribution

The greater wax moth is cosmopolitan. Its distribution is mainly limited by its inability to persist for long at very low temperatures; at high altitudes *G. mellonella* causes practically no damage at all (Paddock, 1928).

Economic impact

Estimations of the economic significance of the greater wax moth were done in the USA where the recorded annual losses were comparable to those caused by American foulbrood (5 million $, which includes the costs for sanitary inspection in the States). These losses amount to 1$ per colony in California, 3$ in Florida and 1.5$ in Texas, where 5% of hives are destroyed annually by *G. mellonella* (Paddock, 1918). In Louisiana in 1969 the losses were estimated at over 30,000$ (Oertel, 1969). The greater wax moth may also cause severe losses to queen producers in Georgia and California.

Morphology

Galleria mellonella (Fig. 4) is a moth of an apparent uniform grey, but an examination of the upper surface of the anterior wing shows reddish brown spots. The female is distinguished from the male by its slightly whitish posterior wings and its larger size; 20 mm against 16 mm maximum for the male. The female can weigh up to 169 mg.

The male has a round head, which in the female is rather elongated. The size and colour of both sexes vary considerably depending on the diet of the larva. Adults from larvae fed on wax foundation are of a silvery white colour whereas those fed on broodcombs appear brown, dark grey or nearly black. A slower development of the larva due to poor diet or low temperatures gives rise to smaller adults.

A newly hatched larva is a ceramic white colour which turns grey to dark grey on its dorsal and lateral surfaces as the larva ages. Larvae can reach a size of 28 to 30 mm in length with a maximum weight of 240 mg (Hase, 1926). Their very small chestnut brown head is strongly chitinised and their mouthparts have two tough and well developed mandibles. The pupae are yellow or reddish-yellow

and are in well developed and tough cocoons. The cocoons are usually whitish but some of them are nearly completely covered with dark particles of excrement. They are 12 to 20 mm long with a diameter of 5 to 7 mm. The last instar larvae often migrate from their feeding site to spin their cocoons on the hive body or inner cover. The number of cocoons which can be counted in a two story Langstroth type hive can reach 10,000, but an average of 250 normal sized larvae can develop in a single old comb. The number of larvae that reach the pupal stage represents about 2/3 of the eggs-laying.

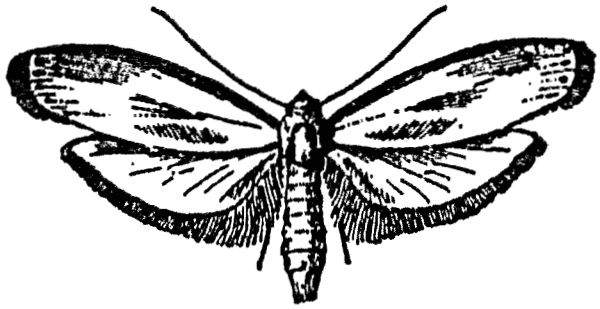

Fig. 4. *Galleria mellonella* after De Layens and Bonnier (1946).

Biology

Egg-laying and development time: The developmental cycle of *G. mellonella* varies from 4 weeks to 6 months. In the longer cycle, dormancy takes place in the prepupal stage (Marston *et al.*, 1975). The adults do not need food or water. Adults live from 3 days to up to over 1 month, but most of the fertilized females die after 7 days when they are maintained at 30-32°C (Nielsen, 1971). With lower temperatures longevity increases (19 days at 20°). The female begins egg-laying 4 to 10 days after emergence, producing about 300 to 600 eggs, or even as many as 1800 (El Sawaf, 1950). The eggs are deposited on the wax inside the hives or in cracks and crevices. Females that are unable to enter hives in the evening lay their eggs in crevices outside and the larvae gnaw their way through the hive body and into the hive (Toumanoff, 1939). Laboratory studies showed that newly hatched larvae of *G. mellonella* can be found up to 50 m away from their hatching site (Nielsen and Brister, 1979).

The reproductive behaviour of *G. mellonella* is not typical of Lepidoptera in that the female seeks out the male which releases pheromones and emits short ultrasound vibrations, to attract its partner (Spangler, 1984, 1985). During the warm season the females usually come out in the evening, leave the bee colonies and meet the males in the trees. They return to the hive the next day, in the evening, to start egg-laying, on average 40 hours after fertilisation (Toumanoff, 1939). The fertilised females do not remain in the colonies but fly off very early in the morning to hide in the trees. During wintertime, the few moths observed in hives remain and reproduce inside broodright colonies. They fly off only when the weather is warm (Nielsen and Brister, 1977). The bees do not visibly react to the presence of *G. mellonella* unless there is close contact. Female moths are attacked more often than males.

Eggs: The eggs of *G. mellonella* are small, yellowish-white grains sometimes with a pink sheen, but they are difficult to see with the naked eye even though most are stuck together in clumps of 100 to 150 eggs. They adhere strongly to the substance on which they have been deposited. By depositing its eggs in places which only its ovipositor can reach, *G. mellonella* effectively places them out of reach of the worker bees. The eggs generally hatch 8 to 10 days after being laid, but at low temperatures this period may be up to 30 days. A brief exposure of *G. mellonella* eggs to extreme temperatures (above 46°C or below 0°C) causes 100% mortality.

Larvae: The eggs give rise to small larvae which measure 1.5 mm in length initially. For their first meal larvae feed on honey, nectar or pollen, if available, or alternatively, wax. Larvae grow quite

quickly and under favourable conditions (adequate temperature and food) they can double their weight every 24 hours during the first 10 days. Larvae grow in a gallery which they bore soon after birth and as the larva grows, the gallery is widened and consolidated with thread which it spins, and with excrement, coating the walls. *Galleria mellonella* caterpillars also spin webs so that the combs become inaccessible to the bees. Moreover, the caterpillars are protected from attack by the bees. About 18 days after hatching, the larvae start to spin their cocoons. Thus, all the combs of a colony are often destroyed 10 to 15 days after the collapse of the bee population.

Developing larvae can feed on all hive products. However, they prefer old combs filled with honey and pollen. The bee brood (larvae and pupae) may also be attacked if the *G. mellonella* larvae are short of food. Observations show that *G. mellonella* caterpillars are highly resistant to food shortage, but under deficient food conditions, their development (from egg to adult) may be extended up to 6 months. Adult insects from poorly nourished caterpillars are smaller with decreased vitality (Marston *et al.*, 1975). In the absence of adequate food supplies the larvae of *G. mellonella* become cannibalistic.

Damage

Galleria mellonella sometimes causes considerable damage and is certainly the most troublesome enemy of bees, destroying weak colonies which succumb to invasion, or causing desertion of infested hives. Strong colonies display a normal behaviour despite the presence of the pest and may eventually manage to get rid of it completely. The moth is undesirable in hives not only because it destroys the wax combs, but also because it hinders the development of bee larvae by tunnelling under the brood cells.

The moths are particularly damaging for stored or built combs in unoccupied hives. The combs become unusable within a few weeks; not only is the wax devoured but the complex network of silk protecting the galleries makes impossible the use of such combs. These must be burned or overhauled, depending on the degree of damage.

The threat presented by *G. mellonella* to bee colonies is not only because of the direct damage it causes in the hives but also because of the transportation of infectious germs. The intestines of the insect often harbour the spores of *Paenibacillus larvae*, the causative agent of American foulbrood. The spores may be released in other colonies in the faeces (Toumanoff, 1939).

Diseases and enemies of G. mellonella

Metalnikoff (1922) observed that *Galleria mellonella* was subject to natural epizootics due to certain viruses and bacteria. Significant mortality can be caused by the presence of microbes in the intestines or in the "blood" of caterpillars. Normally, caterpillars have a very scant microbial flora comprising only a *Micrococcus* spp. and a yeast (Toumanoff, 1951). In 1968, *G. mellonella* larvae infesting apiaries in Louisiana were found to be infected with a new strain of *Bacillus thuringiensis* Berliner (Barjac and Thomson, 1970). Spores of different strains of *B. thuringiensis* are now commonly used to control various species of harmful Lepidoptera. Among the Protozoa, *Coelogregarina* sp. and *Nosema galleriae* can cause fatal infections in *G. mellonella.*

Some Hymenoptera specifically attack *G. mellonella.* In the Ichneumonidae group, *Eupelmus cinereus* Rondoni is a parasitoid of *G. mellonella* found in hives and in wax comb debris (Beljavsky, 1927). A polyphagous chalcidian, *Dibrachys boucheanus* Ratzb, also parasitises the caterpillars of *G. mellonella*. A braconid Hymenopteran harmful to *G. mellonella*, *Apanteles galleriae* Wilkinson (Singh, 1962) is found worldwide.

Control methods

Control of the moth can be undertaken in various ways. The damaged, invaded comb is best cut out and weakened colonies united, to strengthen them. It is advisable to maintain strong colonies and provide the appropriate number of frames for the size of the colony.

Although trapping active moths is most effective, the eggs, larvae and pupae must be destroyed as well. To destroy the insects in the larval stage, the infested combs must be removed from the hives and fumigated with chemical products or subjected to high or low temperatures.

Chemical means: Different chemical agents such as sulphurous gas (SO_2), acetic acid, methyl bromide, ethylene dibromide, paradichlorobenzene (PDB), calcium cyanide and phosphine have been used in different countries to protect hive products (Bailey, 1981; Burges, 1981). PDB, one of the least dangerous products to use, cannot be used on honey combs and it has no effect on the moth eggs. Fumigation with carbon dioxide (atmosphere made up of 73.4% CO_2 and 20.9% nitrogen) kills all the larvae, the most resistant stage, at 38°C in 28 hours (Cantwell and Smith, 1970).

Non-chemical methods: Treating beekeeping equipment and hive products at temperatures not tolerated by *G. mellonella* is a safe and relatively quick method of eliminating the infestation and, like fumigation with carbon dioxide, heat treatments have the advantage of not contaminating hive products with chemical residues. After being exposed to low temperatures, e.g. -7°C for 4.5 hours, -12°C for 3 hours or -15°C for 2 hours, all life stages are killed (Cantwell and Smith, 1970). Good hygienic practices make it possible to minimise the damage caused by the wax moth.

Small insect populations can be targeted and some of the new manipulation techniques for these populations may constitute effective control methods for *G. mellonella.* The populations remain low, even in warm climates, except in depopulated colonies, as the worker bees constantly clean the hives and eliminate the developing larvae. Other methods include the use of biological control agents such as *Bacillus thuringiensis* and the nuclear polyhedrosis virus of *G. mellonella*, genetic manipulations (releasing sterile insects), the use of growth regulators and oviposition attractants. A water soluble concentrate of spores of *B. thuringiensis* Serotype 7 (Cantwell and Shieh, 1981) provides an excellent protection of stored combs without affecting the organoleptic properties of the honey.

The nuclear polyhedrosis virus of *Galleria* sprayed on stacked combs ensures good protection (Dougherty *et al.*, 1982). Traps containing attractants such as pheromones and odours of food are used effectively against insect populations but traps with pheromones were found to be of little use against *G. mellonella* as the males use a combined pheromone and ultra-sound vibration system to attract the females.

Numerous hormones play a role in the regulation of growth and development in insects. Several juvenile hormones are involved in aspects of embryonic development, moulting, reproduction and behaviour. The emergence of wax moths is inhibited by the application of the JH analogues methoprene (Hussein, 1983), or epofenonane (Riddiford and Truman, 1978), inside the hive. However, these compounds are not specific to Lepidoptera, so undesirable effects on bees may occur.

The lesser wax moth: *Achroea grisella*

The *Achroea* genus is made up of only one species, *Achroea grisella*, which is less widespread than *G. mellonella* having a scattered distribution in tropical and temperate climates. The moths of *Achroea,* known as the "lesser wax moth", resemble *G. mellonella* but are smaller; the males are rarely more than 10 mm long, females can be up to 12-13 mm (Kunicke, 1930). The head of *A. grisella* is ochre yellow. The anterior wings are brownish grey, the proboscis is short and the labial palps are turned upwards in the males and forwards in the females.

The caterpillars are a smaller size than those of *G. mellonella* and they make their galleries differently. In contrast to the caterpillars of *G. mellonella*, the caterpillars of *A. grisella* cover their cocoons and galleries with their black excrement so completely that the silky threads, which constitute the basis of all their constructions, cannot be seen through this envelope.

The main feature of the biology of the lesser wax moth is the difference in the life span of the male and female; about 23 days, and 7 days respectively (Kunicke, 1930). The incubation period of the egg varies depending on the temperature: only 5 days at 30°C and 22 days at 16°C. No hatching takes place at all if the temperature is below 16°C. The number of eggs laid by *A. grisella* during its short life, has been estimated at 250-300. The youngest larvae are identical to those of *G. mellonella* but, in the

hive, it is possible to distinguish them by the type of damage the larvae cause; the galleries of the lesser wax moth at the base of the cells, are straight and several centimetres long, rarely traversing the median wall. These depredations cause an abnormality in the brood called tubular brood (Borchert, 1974).

Other Lepidoptera

Apart from the greater and lesser wax moths, various other moths can be found inside hives such as the "deathhead moth" *Acherontia atropos*, a notorious enemy of bees in many countries. The deathhead moth belongs to the Sphingidae family of moths and the genus *Acherontia*. *Acherontia atropos* is one of the largest moths known (Fig. 5).

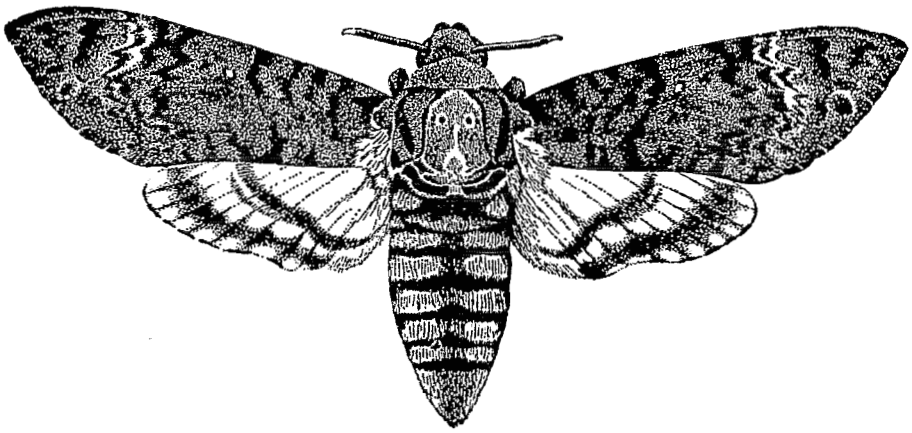

Fig. 5. *Acherontia atropos* after Toumanoff (1939).

The body of *A. atropos* is 5.5 cm long and its width, with opened wings is 11 to 13.5 cm across. The scaly thorax, a deep brown colour, sometimes with a bluish sheen, has a brownish yellow design bearing a strange resemblance to a deathhead with two crossed bones below. It is this design which gives the insect its name; the same in all languages. The large abdomen of the moth is circled with yellow and black with a blueish longitudinal stripe. Its anterior wings are a dark brown with black and ochre yellow spots. The posterior wings have two black transverse stripes, the external stripe being wider than the internal one. It has very robust legs; the tibias have spines and the last section of the tarsi have strong claws. The last two pairs of legs each have a pair of spurs. The caterpillar of this insect can sometimes measure up to 15 cm (Beljavsky, 1927).

The "deathhead moth" is a nocturnal moth of Europe, Africa and Asia which enters hives to steal honey to which it is most partial, even though the adults basically feed on sap (Brugger, 1946). In large numbers it is capable of rapidly depleting the stores in a colony, but the disturbance it creates is much more serious than the loss of a few hundred grams of honey, because the queen and worker bees may abandon the hive. It is difficult for the bees to remove this intruder.

Coleoptera

The order Coleoptera, the largest in the insect class, comprises at least 40% of all insect species. Some Coleoptera cause moderate damage to colonies but most are occasional visitors to hives and feed on pollen and on debris. Representatives of 22 families have been found in pollen traps (Leonard, 1983). In general, Coleoptera are found at the bottom of weak colonies and in stored combs.

Larvae of Coleoptera

The larvae of Coleoptera (*Meloe* spp.) first named *Pediculus apis* by Linnaeus and now known as triungulins, develop from eggs laid in thousands in the soil, or on plants or sometimes at the entrance holes of ground nesting Hymenoptera. Adult Meloidae are harmless for bees but the triungulins are not. These tiny larvae (1 mm long) with their relatively large heads and legs with claws (Fig. 6) are very agile and they actively climb on plants and sometimes even up into the branches of orange trees, where they hide in the flowers and lie in wait for aculeate Hymenoptera. They quickly climb onto the forager bees and cling on to them by hiding in the interstices of the abdomen and the thorax. These phoretic larvae are sometimes so numerous that they can kill the bees simply by overloading. The triungulins, safe from their hosts, are transported by them right into the hives. Once inside the colonies, the triungulins drop off, attack and devour eggs, brood (*M. cicatricosus*), honey (*M. proscarabeus*) and pollen. Some, like the larvae of *M. variegatus*, are even capable of sucking the haemolymph of adult bees which succumb with convulsive movements (Bailey, 1981).

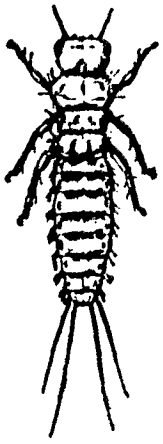

Fig. 6. *Meloe* spp. larva after De Layens and Bonnier (1946).

In Russia and in Iran, observations were made of bee deaths after an invasion of triungulins, which normally takes place at the end of May, or the beginning of June (Beljavsky, 1933; Minkov and Moiseev, 1953).

Coleoptera of bees

In the family of Cetonidae, *Cetonia apaca* (*Cetonia carduii*) and *Cetonia morio* are two species reported to be harmful to bees. The cetonias get into the hive to feed on honey whilst digging galleries in the wax. In some areas of North Africa when there are massive invasions, the honey harvest can be compromised. The bees can combat them only with great difficulty but it is not rare to find propolised intruders inside the hive.

Trichodes apiarus, a small black Coleopteran of the Cleridae family, with red stripes on the elytra, have a particular liking for umbelliferous flowers on which they lie in wait for passing insects, including foraging bees (Beljavsky, 1927). The females look for solitary bee nests to lay their eggs but they can also lay them in weak colonies of honeybees. Pinkish, very hairy larvae with black heads hatch out (Fig. 7). These may or may not, according to different authors, attack brood and damage the wax combs (Toumanoff, 1939; Paillot *et al.*, 1949; Borchert, 1974).

In the Ptinidae family ("Spider coleoptera"), *Ptinurs fur*, can cause quite considerable damage to stored wax combs similar to that caused by the lesser wax moth (Toumanoff, 1939). The same damage can be seen in weak colonies. This omnivorous coleopteran attacks different food sources of

animal or vegetable origin and may play a role in the spread of diseases by excreting bacteria after feeding on combs from infected hives.

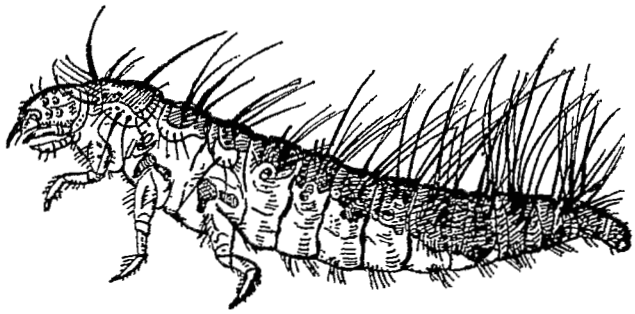

Fig. 7. *Dermestes* spp. larva after Auber (1960).

Diptera

Some Diptera are inimical to the bee. These insects have a single transparent pair of wings with longitudinal veins; the second pair of wings has been replaced by special organs, the halters. True Diptera are most often oviparous, their larvae sometimes legless, with or without a head. The mouthparts of acephalous larvae are most often made up of 1 or 2 chitinous hooks. Larvae with heads possess well developed mouthparts. Diptera frequently parasitise humans and animals. In the larval stage they live at the expense of plants or parasitise animals, causing myiases.

They are subdivided into two main groups: the Nematocerae and the Brachycerae. The individuals of the second group have short antennae, a solid body, the larvae being acephalous, the nymphs mobile or immobile, *cyclorrhaphous* or *orthorrhaphous.* The Brachycerae abound in nature and are subdivided into numerous families.

Of interest are only those which are true enemies of bees (predators, ectoparasites, endoparasites, saprophages and mimetics). Some of them, in certain regions, can cause significant damage but Diptera inimical to bees do not seem to be capable of endangering colonies in the Mediterranean region.

Asilidae

Predatory Diptera, the Asilidae or "robber flies" are carnivorous "flies", attacking a range of insects. The relatively large adults (0.4 to 0.6 cm long) feed on flies, wasps, dragonflies, grasshoppers and moths; the bee is only one prey amongst many. Their head, like that of most predatory insects, is wide, short and highly mobile. The large eyes are set more widely apart in the male than in the female, and they possess a short, strong and rigid proboscis. The proboscis is most often oriented forwards and adapted to pierce the integument; it is even capable of perforating the very hard chitin of some insects such as Coleoptera, Hymenoptera, etc. (Toumanoff, 1939).

The thorax in most cases is strong and prominent; the wings are large and narrow. The elongated abdomen is made up of eight segments, the last ones being narrower than the first. There are several thousand species of Asilidae in the world. Species that prey on the bee have been described in all continents except Australia and Antarctica. Some species may be locally abundant and may thus affect bee populations (Linsley, 1960). It was noted that in the sub-family of Laphriinae there is an insect belonging to the *Nusa* genus, *Nusa atra* species (syn. *Laphria atra* Fabricius, *Asillus ater* Mullet, etc.) which attacks bees.

This insect, common throughout Europe, Algeria and the Canary Islands is a black fly with a violet sheen. The internal surface of the anterior pair of tibia is covered with whitish bristles. The wings are

dark grey with dark veins. The body length varies from 16-18 mm. The larvae live in pine stumps, especially in cut wood. It has been described as an enemy of bees by several authors (Beljavsky, 1927). The common names given to some species of Asilidae reflect their tendency to hunt bees. For example, *Promachus fitchii*, an Asilid of North America is known by the name of bee killer of Nebraska. Studies on predation by the Asilidae show that they most often feed on the larval stages of harmful insects rather than on bees and thus must be considered as useful.

Sarcophagidae

The Sarcophagidae family has over 2500 species, most of which are saprophagous. Some are parasites especially of Coleoptera and grasshoppers.

Senotainia tricuspis Meigen is a well known endoparasite of the honeybee. It causes apimyiasis which can sometimes be quite serious. More frequent in sunny and warm regions, this parasite is widespread in Mediterranean countries (Spain, Rumania, Italy, Tunisia, etc.). Parasitic only in the larval stage, *Senotainia tricuspis* females attack foraging honeybees and drones, and occasionally bumble bees and solitary bees. The female is viviparous (Fig. 8). Its behaviour and its technique in attacking the bee are remarkable. According to Simintzis (1949) it takes up a position, usually at hot times of the day, on the roof of a hive directly exposed to the sun. From there, it dives for the bee just as it is taking off and deposits on it one or two tiny larvae which traverse the thin membrane between the head and the thorax and finally penetrate the latter. It flies back to its position, and after a while repeats this behaviour, sometimes every 6 to 10 seconds during sunny hours. A female can produce 700 to 800 larvae (Simintzis, 1949; Giordani, 1956; Boiko, 1959).

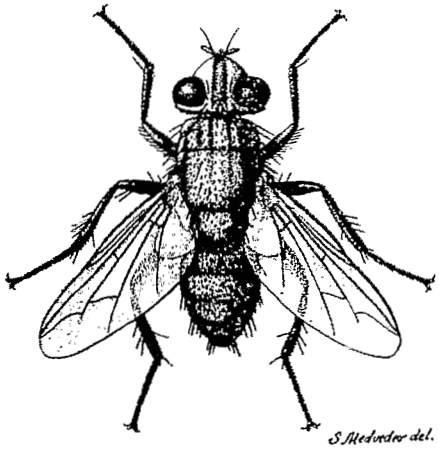

Fig. 8. *Senotenia tricuspis.*

After the larva penetrates the thoracic muscles, it changes into the second larval stage, which feeds on haemolymph for as long as the host survives. This larva is white with black, scythe-shaped mouthparts, 1.5 mm long and 0.5 mm wide. When the host bee dies (2 to 4 days after parasitisation), the larva feeds on the solid tissues and changes into L3. It devours the thoracic muscles, the other soft parts of the thorax and the head. When it reaches 8 to 9 mm in size, it abandons the dead body, buries itself underground to undergo metamorphosis and changes into an adult within 7-12 days (Boiko, 1958) or 16 days (Giordani, 1956). A winter diapause may take place. The imago looks like a domestic fly measuring 5 to 8 mm long. It is characterised by a yellowish white silky cephalic stripe between the eyes. The larvae of *Senotainia tricuspis* must not be mistaken for those of *Apiochaeta rufipes*, a saprophagous insect whose larvae are found only in the bodies of already dead bees.

To control *S. tricuspis*, it is recommended to paint the roof of hives (lookout spot) with a particularly resistant contact insecticide.

Braulidae (bee lice)

The insects called bee lice are not really true lice (orders of Anoplourae and Mallophagae). The tiny adult Braulidae (1.2 to 1.5 mm long) are Diptera characterised by the absence of wings and halteres, with reduced antennae and eyes, a compact thorax and legs with claws transformed into combs specially adapted for clinging to the body of bees.

Braula coeca Nitzsch (Fig. 9), like the other members of the Braulidae family, lives as a commensal in the colony and is transported by bees (phoresy). The insect has always attracted attention, being mentioned in beekeeping literature since 1740.

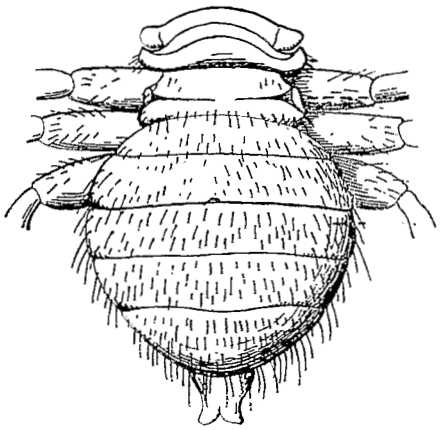

Fig. 9. *Braula coeca* after Toumanoff (1939).

Present on all continents (Nixon, 1982; Smith and Caron, 1984; Bradbear, 1988), *B. coeca* is a rounded, brick-red insect 1.2 to 1.5 mm long and 0.9 mm wide. Its mouthparts are of the sucking type, not adapted to pierce the cuticle of bees. Despite its species name (coeca), it is not blind but has rudimentary eyes which are adapted to the relative darkness of the hive. Gripping the hairs of the thorax or around the neck, it spends its life on the bee. It is most commonly found on the queen, feeding when the nurse bees regurgitate food. The female *B. coeca* lays eggs, which measure 0.72 to 0.75 x 0.24 mm (Borchert, 1970), on the inner side of the cappings of honey cells. The female deposits her eggs in such a way that the larva will hatch from the side facing down. Upon hatching, the larvae tunnel in the wax layer of the cappings and in the median cell walls, feeding on honey and pollen stored in the cells. The whole development of the bee louse takes place in these tunnels.

Considered as inoffensive, the bee louse can, if present in considerable numbers, disturb the egg-laying of the queen and in some cases cause its death. The apparent predilection of the bee lice for the queen is probably because she is the most permanent member of the colony and the frequency of feeding and quality of food is greater than that of the worker bees.

Measures against the bee louse

A brief exposure to tobacco smoke is effective in narcotising *B. coeca* which are then collected on an oiled sheet of cardboard inserted at the bottom of the hive prior to the operation (Bertrand cited in Phillips, 1925). Chemicals such as bromopropylate and phenothiazine have been used for fumigation. To destroy the immature stages of *B. coeca*, the cappings of affected honey combs can be removed (Atakishiev, 1971).

Hymenoptera

The order Hymenoptera comprises the bees, ants and wasps. Amongst the most interesting species, are those that are social. Predation behaviour is particularly significant when it is displayed by these social species; co-ordinated attacks by several individuals being possible. All the ants (family of Formicidae) live in organised societies. This is also true of wasps in the sub-families of Polistinae and Vespinae in the family Vespidae.

The most dangerous predators of bees belong to the family Vespidae (wasps and hornets) and the family Sphegidae (*Philanthus apivorous*). In some years the "wasps" have no hesitation in entering weak hives and taking the honey or worker bees and hornets readily choose apiaries as their hunting ground.

Formicidae

Despite their small size, the ants, because of their numbers and their habits, are the most outstanding invertebrate predators of terrestrial ecosystems (De Jong, 1990). The ants have a predilection for sweet substances (sugar, honey, jams, sap) and through stimuli, make aphids exude honeydew, thus depriving the bees of this food source. Ants also play a useful role as cleaners by removing dead or dying bees from the apiary, thus eliminating possible sources of diseases.

Ants may harm bees in various way. Some species, in particular those in the sub-families of Dorylinae and Ecitoninae, which include the army ants, are capable of destroying a whole apiary within a few hours. They behave as fearsome predators of adults, larvae and eggs. Other ants disturb the colony in their eagerness to steal honey (*Formica rufa*, *Formica sanguinea*, *Formica fusca*, *Lasius niger*) or pollen (*Crematogaster jherinji*) (Santis and De Regalia, 1978). Other species such as *Camponotus herculeanu* ssp. *pennsylvanicus* attack the wood of the hives or their supports (Burril, 1926). Generally, most of the ant species are not very damaging to bees even though they occasionally roam around inside the hives, looking for food. Also, they may establish their nests between the cover board and the roof, taking advantage of the warm, humid environment, which provides them with optimal nesting conditions. Queen mating nuclei containing very small populations of bees, are most vulnerable to attack by ants.

Means to combat ants

Control measures against ants should only be taken in the case of persistent problems. Numerous methods are advocated of varying efficacy. Those most commonly used are:

(i) For the hive: painting the legs with petrol or waste oil; use of repellents placed between the roof and the cover boards (ethanol, sodium fluoride, sulphur, borax).

(ii) For ant nests: applying toxic baits or spraying insecticide (diazinon, synthetic pyrethroids).

Vespidae

The social wasps of the sub-family of *Vespinae* belong to one of five genera: *Provespa*, *Vespa* (hornets), *Dolichovespula, Paravespula* and *Vespula.* In contrast to bees which erect vertical combs, the social Vespidae build horizontal constructions made up of single rows of cells. When searching for food (two sort of substances: sweet saps of plants and small invertebrates) the "wasps" attack different kinds of insects, including bees.

The first observations on predation of honeybees by wasps, go back to the Roman period (De Jong, 1990). Predation and pillaging of hives continues today and the hornets, in particular, sometimes constitute a serious economic problem in some regions. *Vespa crabo* is one of the most widespread species of hornets. This bold predator usually builds its nest in cavities in hollow trees and old walls, but sometimes under ground. Its large size enables it to readily capture foraging bees at work and even at the hive entrance. The hornets have this curious attitude of swooping down on anything dark

on the flower (De Jong, 1979). *Vespa crabo* can undertake co-ordinated attacks with such a great number of individuals that whole apiaries may be depopulated. The bees cannot, on their own, offer great resistance to the hornets.

Wasps of the *Vespula* and *Dolichovespula* type are not important predators of bees. The German wasp, *Vespula germanica* (*Paravespula germanica*), forming colonies with thousands of individuals, nests in the ground. It steals honey mainly and is a predator of foragers secondarily, like the common wasp, *Vespula vulgaris* (*Paravespula vulgaris*), a related species, which also nests in the ground.

In view of the role played by the "wasps" in biological equilibrium, measures to control them should only be undertaken in extreme cases.

Sphegidae

The Sphegidae constitute the most remarkable group among the predatory Hymenoptera as they have the ability to hunt and paralyse their prey with which they feed their larvae. They hunt all kinds of insects in the larval or adult stage, some primarily spiders, although it is quite rare for a Sphecoida to prey on only one species. This is nevertheless the case for *Philanthus triangulum* (or *Philanthus apivorous*) which most commonly hunts the managed honeybee (rarely other Apidae), sometimes killing numerous individuals (Evans and O'Neill, 1988) (Fig. 10).

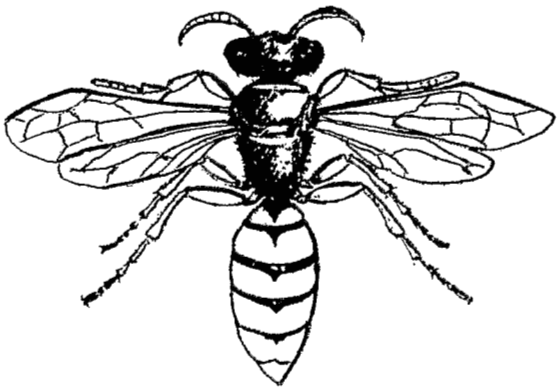

Fig. 10. *Philantus triangulum* after Borchert (1970).

Philanthus spp., the best known parasites and enemies of bees, commonly called the bee wolf, is a burrowing Hymenopteran 12 to 16 mm long, with a wide and powerful head with strong mandibles. The thorax is black, decorated with a yellow design, variable in shape. The abdomen is yellow, sometimes with dark triangular spots on the dorsal side of each segment. In the male, the triangular spot on the dorsal side of the abdomen is more pronounced than in the female (Toumanoff, 1939). The fertilised females burrow into the soil to construct the nest, preferably located on sandy slopes and on sunny dunes.

The female deposits its eggs on the bees it captures and then transports them to its nest. The bees brought into the nest serve as food for the larvae, but they also hunt bees to feed themselves. In the Mediterranean region the bee wolf is most active in July. The female lays about fifteen eggs, each supplied on average with 5 bees. If the insect itself consumes three times more than the larva, which is reasonable, it becomes obvious that each *Philanthus apivorous* can destroy three hundred bees during its life-span of a season. About a hundred individuals would be sufficient to adversely affect a colony (Picard cited by Toumanoff, 1938). Fortunately, *Philanthus* spp. do not always attack bees from the same colony, but in conjunction with other enemies they contribute to the depletion of the adult bee population (Simonthomas and Simonthomas, 1980).

Control measures

Measures against the bee wolf are the same as those used against the ground nesting wasps but they are much more difficult to apply because the bee wolf nests are not easy to find. Encouraging vegetation to grow within the apiary prevents nest digging by the adult insects. Thiem (1935) advises that when the insects appear in large numbers, the adults can readily be captured because they fly very slowly when loaded with their booty. This author suggests that good control can be obtained by covering the nest sites with an asphalt solution in a cold water emulsion. Simonthomas and Simonthomas (1980) recommend that apiaries be moved away from heavily infested areas so that the adults are deprived of bees and local populations of this predator are thus reduced.

Amphibians

Different species of Bufonidae (toads) feed on bees whilst the Ranidae (frogs) may swallow one occasionally. However, both are useful animals as they help to limit the population growth of molluscs, worms and parasitic insects. If they become a nuisance to colonies it is easy to protect them by raising them off the ground.

Birds

For many birds, insects form a major part of their diet. The bee sometimes constitutes a prey of choice and the apiary is an ideal hunting ground. However, in general, birds create minor problems for beekeepers.

In temperate areas, several species occasionally catch bees in flight, in the same way as toads and lizards, but in addition, some species may disturb the bee colony. The tits, and especially the great tit, *Parus major*, capture bees to feed their young, but do little harm to strong colonies. However, during periods of scarcity in the winter, they may persistently tap on the hives to catch the worker bees drawn to the entrance. *Merops apiaster*, commonly known as the bee-eater, is a very beautiful bird with brilliant plumage (Fig. 11). It is a tireless insectivore and surprisingly skilful in catching bees in flight which constitute 70% to 80% of its diet. In one season a pair of birds can consume up to 30,000 bees (Borchert, 1974). The problems caused by bee-eaters in some areas of the world means that the beekeeper must move the apiary or take some action to control the birds.

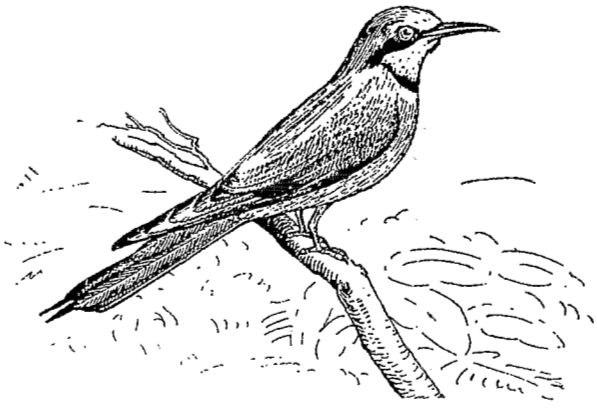

Fig. 11. *Merops apiaster* after Toumanoff (1939).

Mammals

Mice

Mice are known everywhere as a nuisance to bee colonies. The main species, the domestic mouse (*Mus musculus*) and the wood mouse (*Apodemus sylvaticus)*, can enter hives and destroy stored apicultural equipment. The mice feed on pollen, honey and on bees. Their attacks can result in the loss of a whole colony or in its exhaustion. The mice create space for their nests by gnawing at the combs. They are capable of building their nests even in vigorous colonies and of spending the whole winter there without being disturbed. The mice create even more of a nuisance through the smell of their urine and excrement which may cause the bees to desert the hive in the spring (Langstroth, 1860).

Measures against mice

Control measures raise no particular problems. The most widely used method is to reduce the entrance hole. Some beekeepers prefer to install special metal grids whereas others use nails with a spacing of about 1 cm. With abnormally large populations it may become necessary to destroy the mice around apiaries. Best results are obtained with traps and with chemical means using poisoned baits (provided these do not present any danger for domestic animals).

Other mammals

Amongst the carnivorous mammals the jackal, the racoon and some weasels are occasional enemies of bees. In Africa and Asia the nocturnal honey badger is harmful to bees because it is capable of knocking heavy colonies off their stands and carrying off combs. The bear is probably the largest animal harmful to bees. The black bear of North America probably causes the most significant problems, but the brown bear of Europe and three other Asian species are also notorious pests in apiaries.

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