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Chapter One

MEN AND INSECTS

AN attractive but unproved theory suggests that men and insects both owe their origin to a class of creatures often spoken of as *Articulata*, because they are made up of numerous similar rings or segments arranged in a regular series from front to rear. Obvious and fundamental distinctions between the two as they exist today are that whereas men have backbones insects have not, while the principal nerve-cord and the main circulatory organ are differently placed in relation to the body's axis. Yet it is noteworthy that if we take a fairly advanced type of invertebrate, such as a crayfish or a cockroach, and turn it upside-down, we transpose its nerve-cord to the upper side and its heart to the lower side, the positions which they occupy in a vertebrate animal. It seems at least possible, therefore, that vertebrates may have evolved from an ancestry of these aquatic ringed worms which took to swimming on their backs.

This, however, is purely conjectural, and nowadays mankind and the insects have little enough in common, save for the fact that they are both living beings. Nevertheless, a curiously close analogy can be traced between the habits and economy of civilized humanity and those of the social insects. The communities of both are organized, albeit in different ways, to cope with the perennial menaces of over-population and starvation; and it is arguable that in these respects insects have scored the greater success. Their systems are more rigidly communistic, in the modern sense of the word, the well-being of the separate units being ruthlessly subordinated to that of the community as a whole, which is paramount. Reproduction is restricted to one or a few females, known euphemistically as "queens", the bulk of the population consisting of sexless individuals, or "neuters", on whose activities as builders, nurses, foragers and so forth the prosperity of the establishment depends. Social bees, wasps and ants tolerate males in small numbers and for short periods only as fecundating agents, but among termites or white ants members

of this sex not needed for breeding purposes are relegated to the executive as sterile soldiers and workers.

These matters, and the question of how and why they came into existence, form the subject of the following chapters. But by way of introduction something must first be said concerning the structure and development of insects in general and their varied modes of life.

In the absence of a backbone the adult insect is equipped with a hard outer crust, or exoskeleton, laid down by the living cells of the true skin, or epidermis. The soft tissues of the body are thus supported and protected, while points of attachment are provided inwardly for the muscles. Apart from the segmented character of the backbone, adult vertebrates, including mankind, have lost nearly all traces of their conjectural worm-like ancestry. Insects, on the other hand, still retain a definite articulate structure although a sort of telescoping of the originally separate segments has taken place, resulting in a more or less definite constriction of the body into three parts, namely, the head, the thorax and the abdomen. In the head always, and often in the thorax, the component segments are so intimately fused together that the lines of juncture are almost obliterated, but in the abdomen, which remains flexible, they can usually be distinguished without difficulty.

The immediate forerunners of insects in the evolutionary succession appear to have differed from the less specialized round-worms in that each of their segments carried a pair of locomotor appendages which at first were mere bristles but in the more advanced types became jointed limbs. As time went on several segments seem to have been pushed forward, so to speak, into the neighbourhood of the mouth, so that their appendages—primarily functioning as feet—could be used for nipping and biting. This is why members of one great phylum or sub-division of the animal kingdom, with insects in their van, are termed Gnathopoda—i.e. “foot-jawed”.

Insects have three pairs of mouth-parts situated behind the so-called upper lip or *labrum*, which is hinged to the head in the middle line. First come the *mandibles*—powerful nipping organs, especially serviceable for breaking up hard or tough substances. Then there are the *first-* and *second-maxillae*. Unlike the mandibles

each of which is in one piece, these retain their primitive jointed character, being severally composed of two basal and two apical parts, while each carries a *palpus* or feeler. The first maxillae, like the mandibles, are separate, but the bases of the second pair are frequently more or less closely united, and for this reason are often referred to *en masse* as the *labium* or lower lip, on the front side of which is the *ligula* or tongue—usually an insignificant, skinny fold, but in some instances of considerable length and importance.

The above description applies in the main to insects, like a cockroach or a beetle, which subsist chiefly on solid food. But many kinds feed either wholly or in part on liquids. Some suck nectar from flowers; others pierce the cuticles of plants or animals and imbibe the sap or blood. The adoption of such methods of feeding clearly necessitated deep-seated changes in the structure of the mouth-parts. In butterflies and moths, for example, we find them transformed into a trunk or proboscis, often of great length, which is coiled up like a watch-spring beneath the head when not in use; while a gnat or mosquito is furnished with six stabbing and probing instruments wrapped round by a grooved sheath. Bees have their maxillae variously modified to serve as an apparatus for extracting the sugary juices from the blossoms that are visited, but their mandibles are retained as biting organs—as, indeed, is the case with all other social insects, whether or not they are flower-frequenterers.

Most adult insects have two sorts of visual organs, namely, a pair of large, many-faceted eyes, one on each side of the head, and two or three small ones upon the brow. The latter, termed ocelli or simple eyes, are tiny polished lenses mounted above a cup-shaped mass of pigment cells forming a visual area or retina. Their focus is so short that probably their chief use is for estimating light intensity. Bees, wasps and some ants have three of these eyes arranged in a triangle on the front of the head, but in other ants they are absent, while many termites or white ants are quite blind. The many-faceted or compound eyes often consist of very numerous lenses, but in certain worker ants the number may be fewer than a dozen. Each lens is capable of projecting an image of the object before it—a fact which led the early naturalists to conclude that a multiplicity of separate

pictures must be presented for inspection to the insect's brain. But this notion was long ago discarded in favour of the more plausible one that only a very small portion of the field of vision is transmitted by each facet or lens to the retina, where the fragmental images combine—like a mosaic pavement!—to form a continuous impression.

In addition to the mouth-parts and eyes, an insect's head carries the important sense-organs called feelers or antennae. These are largely tactile in function, being used to explore the surface of objects and for examining food. Social insects seem to have evolved a kind of deaf-and-dumb language enabling them to exchange information by tapping and stroking each other's antennae. But observation and experiment have shown that in many instances these organs are not merely "feelers" but fulfil also the functions normally performed among vertebrate animals by ears and noses. Moreover, it appears probable that insects are endowed with a sense or senses without parallel in human experience.

Extensive structural elaborations of the antennae, such as characterize those of certain moths and beetles, do not occur among social insects. The antennae of termites are simple, consisting of a number of consecutive joints—like a string of beads: those of bees, wasps and true ants are of the elbowed type called geniculate, having a long, basal joint (the *scape*) to which a series of lesser joints (the *flagellum*) is attached in a manner suggesting the lash of a dog-whip. Among these insects the number of joints in the flagellum varies from species to species, but the males usually possess one more joint than the females and neuters.

The thorax or median division of an adult insect's body normally carries six jointed legs and four (more rarely two) wings. The latter are not modified limbs, as is the case with bats and birds, but consist of membranous outgrowths from the exoskeleton supported upon a tubular framework of so-called nervures. The forewings of many insects—e.g. grasshoppers and beetles—are thickened and hardened to serve as protective covers beneath which the more delicate hind-wings are folded away out of sight when they are not in use. Both sets of wings are used in flight by social insects; but among termites and true

ants they are developed only by sexually perfect individuals, and regularly discarded soon after pairing has taken place—if not earlier. All the most highly specialized insects have the two wings of each side united during flight by a mechanical contrivance so that they function as one. In the case of the bees, wasps and their relations, for example, a number of minute hooks on the front margin of the hind-wing engage with a corresponding fold in the hinder margin of the fore-wing—this device being characteristic of the whole group or Order to which these insects belong.

Behind the thorax, attached to it by a stalk or waist, is the hind-body or abdomen, made up of a varying number of rings or segments, some of which are often fused together and otherwise modified, so that their separate identification is not always easy. Those at the tip house the genitalia, which in the female include the egg-laying apparatus or ovipositor. The latter, in the case of bees, wasps and many ants, is modified to act as a poison-injecting sting, the eggs then passing not through the organ but out of an aperture at its base.

The distinction may seem captious to the human sufferer, but the stab of a gad-fly or the bite of a gnat or mosquito cannot properly be called a sting, since it is inflicted by a set of surgical instruments in the service of the mouth, and its object is to tap the victim's blood—not to disconcert or drive away an assailant.

As already indicated, the sting among insects is peculiar to the female sex of wasps, bees and ants. Fossorial or digger wasps employ it to paralyse or kill their prey, but solitary bees and all the social species use it solely as a weapon of defence. The details of its structure vary, but it consists essentially of three parts, namely, a pointed sheath or director within which slide two darts or needles. The first thrust is administered by the director, which thus opens a wound. The needles then strike alternately beyond its tip with a rapid, plunging movement, the while venom is pumped down through the channel between them from the poison-sac or bag. The presence of barbs on the needles may result in the sting and all its attachments being dragged out of the abdomen, with fatal results to their owner. This commonly happens in the case of the worker hive-bee, which is usually too much agitated to perform the slow spiral movement—similar to withdrawing a corkscrew from a cork—by which the barbs could

be released from the wound. The sting of a queen hive-bee, like that of a fossorial wasp, is barbless, and is used only against rival royalties. The sting of a social wasp has barbs, but these do not prevent it from easy withdrawal after use.

The potency of the sting as an instrument of defence may to some extent be gauged by the fact that the guise of its possessors is frequently counterfeited by inoffensive insects, notably moths, two-winged flies and some beetles. A plausible explanation of this phenomenon was suggested by Dr. A. R. Wallace, who pointed out that stinging insects are often so conspicuously coloured that their appearance is likely to impress itself upon the memory of an assailant, which might thus be deterred from attacking their like in the future. If we accept this theory of "warning coloration", it follows that any defenceless insects that happen to resemble or "mimic" those with a sting will participate in the immunity conferred by this weapon. Moreover, one may suppose that parasites and other intruders so disguised would be able more easily to enter the nests of social species without detection.

The case of the hive-bee and its mimetic counterpart the drone-fly is of special interest because the former is one of the relatively few aculeate or sting-possessing insects which are not strikingly coloured. Although its sting is just as deadly as the wasp's it does not advertise the fact in the customary manner—perhaps because its self-assurance and quick resentment of interference render this unnecessary. Anyhow, it is recognized as dangerous and avoided, its sombre livery notwithstanding, and so has served as a model for mimicry. Lloyd Morgan found that young birds, having sampled worker hive-bees and rejected them with disgust, subsequently refused to touch not only drones, which have no stings, but also the mimetic drone-flies when these were offered to them.

The insect's heart is a long pulsating tube by which the blood is pumped directly into the body cavity, where it circulates freely, bathing all the organs, receiving nutriment from the food-canal and carrying away waste matter. Eventually it re-enters the heart through valvular slits in its walls.

The relative simplicity of this circulatory process is largely explained by the fact that the insect's blood is less vitally important than that of a vertebrate animal. It nourishes and cleanses

the tissues, but does not oxygenize them, since insects have no lungs. Breathing is effected through small holes, called spiracles, situated at intervals along the sides of the body. Atmospheric air is thus admitted to a system of ramifying tubes, or tracheae, whose smallest branches—more delicate than the finest hairs—extend to the most distant extremities, such as the tips of the antennae and limbs. Even the tiniest are lined with a spirally coiled thread of hard material—like the metal wire in certain kinds of rubber tubing made by man. In this way the risk of short-circuit is prevented, the elastic coil keeping the trachea open when it is subjected to pressure—as, for example, by the bending of the joint through which it passes.

An insect's central nervous system differs in important respects from that of a vertebrate animal. Its location is beneath the alimentary canal, instead of above it, as is the case with a fish, a reptile, a bird or a mammal. It consists of a brain, which encircles the gullet like a collar, with nerve-cords extending from it to the posterior end of the body and connecting a number of knots, or ganglia, which function as minor brains, directing the activities of the organs in their immediate neighbourhood. The brain, which is closely linked with the compound eyes and antennae, is the chief seat of sensation and co-ordination, but has little to do with the movements of the jaws, legs and wings. The upshot of this is that an insect deprived of its brain can walk or fly in an aimless, erratic manner, because the actual motor-nerves, which send stimuli to the legs and wings, spring from ganglia in the thorax; it can also eat if food be placed in contact with its mouth-parts, the reason being that the nerves from the latter and their palpi are connected with the ganglion situated just behind the brain, beneath the gullet.

In view of these facts it is scarcely surprising to be told that insects in general are markedly deficient in the faculty that we speak of as intelligence. Some of the more highly specialized kinds, particularly bees and ants, appear to retain past impressions—to remember, as we say—and to profit by experience to a limited extent. But in most of their reactions insects are governed solely by what is called instinct. Without instruction or opportunity for imitation, they perform all manner of intricate operations for their own or their offsprings' benefit. The only

possible inference is that, by some as yet undiscovered means, each succeeding generation inherits from its parents a self-acting nervous mechanism, comparable on the material plane to an elaborate piece of clockwork, wound up and ready to perform its destined movements as soon as the spring is released. This release appears to be effected by some simple stimulus, due either to internal or external causes, the nature of which we can often only guess. In this way the wheels are set in motion, so to speak, and the whole amazing sequence of the insect's inherent skilfulness is reeled off.

Their elaborate sensory and nervous equipment notwithstanding, insects are apparently immune from physical pain. Mutilations resulting in the loss of important organs doubtless induce feelings akin to discomfort and inconvenience, but not of bodily anguish such as would be suffered in similar circumstances by human beings. Careful observation and countless experiments all point to these conclusions. The late Rev. Theodore Wood, a trustworthy naturalist, records that on one occasion he induced a dragon-fly—which had been deprived of its abdomen by an ill-aimed stroke of his collecting net—to consume in rapid succession thirty blue-bottle flies, and finally to eat its own severed hind-body! Of course the masticated food simply passed through the thorax and fell out behind, as if from a mincing machine! In an aquarium, a dragon-fly's nymph, engaged in eating the larva of a may-fly, was seized from behind by a large carnivorous water-beetle. Did it abandon its victim and concentrate its energies in a fierce struggle for life and liberty? No! It calmly continued its meal while the beetle gnawed its vitals!

Wasps, deprived of their abdomen, feed greedily on fruit syrup, which—issuing from the truncated part of the alimentary canal—forms a glistening globule where the waist should be. Ants and termites—especially the large-jawed individuals of the soldier caste—will allow themselves to be torn literally in pieces rather than relinquish their hold on an object, whether it be a grass-stem or the head of an enemy, which they have gripped. The Swiss entomologist August Forel, whose special study was the behaviour of insects, sought proof that bees, in their passage from flower to flower, are guided chiefly by sight—not by smell, as was at that

time supposed. With this object in view he cut away the antennae and mouth-parts of some humble-bees, thus robbing them of their olfactory nerve-endings. When liberated in a garden these mutilated insects flew to flowers without the least hesitation, as Forel had anticipated ; but he was amazed to find that they were no less eager than their uninjured companions. They evinced the keenest desire to feed, and were only deterred from doing so by the injury which they had suffered.

Certain popular novelists, notably H. G. Wells, have made diverting play with the notion that the more aggressive and ubiquitous insects, such as ants and wasps, may one day become serious rivals of mankind in the struggle for existence ; but this is a highly improbable happening, for two fairly obvious reasons. In the first place, because of the peculiar way in which they breathe, insects are very unlikely ever to increase much in bulk beyond their present maximum, represented by the Goliath beetles of West Africa and the elephant beetles of tropical America. As we have seen, atmospheric air is admitted to their bodies through lateral apertures, or spiracles, and enters a system of tubes or tracheae whose final ramifications are microscopic capillaries ; and since it can penetrate only by diffusion its flow slows down rapidly as the calibre of the capillaries becomes finer and their distance from the spiracles increases. Hence, if insects were to grow much bigger than they are today we should expect their energies to decrease proportionately, owing to oxygen starvation. So that a really gigantic insect, though formidable in appearance, would probably be too lethargic to cause serious trouble.

In the second place, insects live in a totally different world of experience from that which man has made his own, and in all likelihood only sense his existence in the way in which we are made conscious—as by such occurrences as earthquakes and tornadoes—of vast cosmic forces beyond our control. Their age-long civilization, if so it may be called, is not the outcome of reflection and reasoning, but of blind instinct established and regulated by an apparently mechanical selection, not of the best or brainiest, but simply of the fittest to survive in a particular environment. By contrast, the distinguishing characteristic of man is that he is highly intelligent, and unlike other creatures

can modify his environment in all sorts of ways into conformity with his needs and fancies. Above all, he is an ingenious tool-maker and a prolific inventor. Not Brobdingnagian insects, therefore, but a race of supermen would be needed successfully to contest his supremacy!

With few exceptions the life-cycle of an insect begins with an egg. Among the least specialized, wingless kinds the young hatch out as miniature replicas of their parents, changing their skins periodically and increasing in size as they grow from infancy to maturity. Much more frequently, however, this period of development involves a metamorphosis, or series of form-changes, the winged state being attained only after the final moult; and in such cases the appearance and habits of the immature creature, or larva, are often totally different from those of the adult. Examples are the ugly, aquatic larva of the dragon-fly, and the leaf-eating, worm-like caterpillar of the butterfly. If, as in the latter instance, the transformation is very great, the fully nourished larva ceases to feed and changes to a pupa or chrysalis from the skin of which—after a period of quiescence when the living tissues are broken down and refashioned—the perfect insect emerges. The metamorphosis of such insects is described as “complete”, whereas when no pupal stage intervenes it is said to be “incomplete”.

With these details in mind it is possible to arrange the major divisions or Orders of insects—except the primitive Aptera, which undergo no metamorphosis and never develop wings—under two headings, as follows:

Metamorphosis incomplete
 Cockroaches, Grasshoppers,
 Crickets, etc.
 Earwigs
 Stone-flies
 Termites or White Ants
 May-flies
 Dragon-flies
 Thrips or Flower Insects
 Bugs, Aphides, Scale Insects,
 etc.

Metamorphosis complete
 Alder-flies, Lacewings, etc.
 Beetles
 Scorpion-flies
 Caddis-flies
 Butterflies and Moths
 Two-winged Flies
 Saw-flies, Gall-flies, Ichneu-
 mons, Wasps, Bees and Ants

The most surprising feature of these two contrasted tables is that an elaborately organized mode of communal existence has arisen independently among two groups so widely separated as the termites and the wasps, bees and ants. The latter are probably the most highly evolved of all invertebrates, whereas the termites are scarcely more advanced structurally than the cockroaches. That these co-operative societies originated as the outcome of an intelligent interchange of ideas, such as we may imagine to have occurred among early races of mankind, as a prelude, for example, to the transition from a nomadic to a settled agricultural state, is extremely improbable. Rather we must suppose that they were established solely through the operation of natural selection, which on this view not only brought into being the different grades or castes, reproductive and sterile, but at the same time called forth and correlated their respective instincts so that, although no physical continuity exists between them, they work together harmoniously to promote the prosperity of the association as a whole. In other words, a community of insects functions as a biological individual exactly comparable to a multicellular organism, such as a tree or one of the higher animals, save that the closely adherent and evidently interdependent cells are replaced by separate and to all appearances independent units. Hence, Charles Darwin was justified in concluding that queens emanating from nests whose neuters have achieved the maximum of success in running their community are the ones most likely to perpetuate the species, because in these instances the process of natural selection involves evolutionary changes in the whole community, rather than in any of its individual members.

This brings us to the remarkable fact that among social insects the non-reproductive or neuter castes constantly inherit through successive generations peculiarities of structure and behaviour which are not present in the make-up of their parents. By what means, in the absence of any material connectives, are the determinants of these hereditary factors conveyed from the bodies of the neuters to the germ-cells of their progenitors? One ingenious but so far unsubstantiated solution of this problem has been advanced by Dr. Arthur Dendy. He points out that the means of communication between the various organs of a living body may be compared to the different methods by which

messages are transmitted between distant members of a civilized community. Thus, the circulation of fluids, such as the blood, and the distribution of glandular secretions, may be likened to communication by letter post, while the passage of stimuli through the nervous system suggests ordinary telegraphy over conducting wires. With this simile in mind, "Why should we deny the possibility that a third means of communication, analogous to wireless telegraphy, may also exist?" Why, in short, should not the determinants pass from the bodies of the neuters to the germ-cells of the parents by a method comparable with broadcasting? The close association in which members of an insect community live may be supposed to facilitate such a transfer.

Chapter Two

GREGARIOUS INSECTS

ALTHOUGH the majority of insects lead a solitary existence, except for a brief interlude at the time of courtship and mating, a considerable number of species club together during certain periods of their lives. These temporary congeries, which have been called "imperfect societies", may be roughly classified under six headings, as follows :

1. Associations for companionship and diversion.
2. Associations prelusive to pairing.
3. Associations for migration.
4. Associations for feeding and co-operation.
5. Associations conducive to protection.
6. Associations for hibernation.

To the first of these categories belong the whirligig beetles of which there are about six British species, all very similar in appearance, save to the eye of the expert. They congregate in large or small companies on the surface of clear pools and slow-flowing streams, where they circle and dart in all directions like so many swallows or bats, but with movements far more rapid in proportion to their size. If alarmed, all dive together into the depths, each carrying down a quicksilver-like bubble of air attached to its hinder extremity. When the sky is overcast and at nightfall they cluster in groups under overhanging banks, and in winter betake themselves to the bottom, where they mostly lie buried in the mud till the return of spring, though a spell of exceptionally mild weather may tempt a few to the surface again for an hour or two at midday.

Throughout the year, when calm weather prevails, aerial dances are performed by various species of midges, gnats and the smaller crane-flies, usually in the late afternoon or early evening, their rapidly moving wings, glittering in the level sunbeams, causing a scarcely audible murmur. Dense clouds of midges—like drifts of smoke—may often be seen on still days in spring or early summer near the ditches and ponds in the mud of which

their aquatic larvae—known popularly as “blood-worms”—live in little colonies, each in its separate burrow. In sheltered situations crowds of the common winter gnat issue from their hiding-places when the sun breaks through the clouds, even when the ground is covered with snow. The swarms of these and a number of other two-winged flies rise and fall in rhythmic unison with such an appearance of infectious gaiety that the human observer is prompted to ask with Wordsworth what other spirit than one of “participation of delight” can prompt them thus

to mix and weave
 Their sports together in the solar beam,
 Or in the gloom and twilight hum their joy?

In most instances, however, the components of such associations are almost exclusively masculine, which suggests that they play a significant part in what may be called the courtship ritual of the species concerned by providing opportunity for the males to attract and secure mates. This is certainly the case with the two large, mottled-winged may-flies whose hymeneal habits have been closely studied. The females, on leaving the water and attaining their perfect winged state, hide for a while among vegetation, but later flutter by twos and threes into the crowd of dancing males, and pairing takes place in mid-air. Whether proximity or some more subtle factor determines the actual union is not clear; but since female may-flies vastly outnumber the males, myriads of the latter must inevitably perish in bachelorhood. That we have close on fifty species of may-fly in Britain will surprise those who are only acquainted with the two mentioned above. The rest are all small and inconspicuously coloured, the tiniest with a wing-expanse of only one-quarter of an inch. Despite their popular name the different kinds appear at intervals throughout the summer, some mingling with the contemporary swarms of midges, for which they are apt to be mistaken.

Other kinds of two-winged flies that are frequently much in evidence in the springtime belong to the genus *Bibio*, especially notable for the difference in colour of the sexes, the females for the most part being yellow or orange-red, the males wholly black. One of the commonest species is the St. Mark's fly, so named

because it usually appears about April 25th—St. Mark's Day in the ecclesiastical calendar. These insects are sluggish in habit, spending most of their time on vegetation and seldom taking to flight. Despite the enormous numbers in which they sometimes occur, and the fact that their larvae feed on roots in the soil, only one of them appears to be really injurious in Britain—namely, the so-called fever-fly of our hop gardens.

On mild evenings in May and early June—and again later in the season—swarms of chafer beetles of several species may be seen hovering over the tree-tops and hedgerows. These consist entirely of males, the females being hidden among the foliage, and not becoming active until after pairing has taken place, when they descend to the ground to lay their eggs in the soil—the resulting larvae figuring as “white grubs” among agricultural pests.

Insects sometimes congregate in prodigious numbers for the purpose of travel, presumably in search of food, certain kinds of larvae having gained the title of “army worms” in this respect. The half-grown caterpillars of the white-speck wainscot moth are apt to assemble in countless hordes which overrun grass and corn lands, working incalculable havoc. These invasions take place most frequently in the North American continent; in Britain the moth occurs only as a rare immigrant. Our chief “army worms” are the caterpillars of the antler moth which in some seasons—usually in mountainous districts—make their appearance in vast multitudes which travel from field to field, devouring the crops as they go.

Other so-called “army worms” are the maggots of certain fungus-gnats or midges belonging to the genus *Sciaria*. One species, which lives under layers of rotting leaves in the forests of northern Europe, at times migrates from one feeding ground to another in weird, snake-like columns. Millions of the maggots, held together by their viscous secretion, form great strings or ribbons several inches thick and many feet in length; and it is said that if by chance the two ends of one of these are brought into contact, they become joined, and the ring may writhe for many hours before it can disengage itself. Sooner or later the columns coalesce into masses which slowly disintegrate as their units burrow beneath the leaves in search of food. Other species of these

maggots are met with in North America, and in the southern United States one, in the adult, winged stage of its life-cycle, is known as the "yellow-fever fly", since on more than one occasion it was noticed to be particularly abundant during epidemics of this disease—with which, however, it is in no way connected.

A number of butterfly species habitually congregate in migratory swarms which have surprising powers of flight, often winging their way to regions far distant from their place of origin. This appears usually to happen as the result of over-population and the need to seek fresh feeding areas, but other incentives doubtless operate from time to time. Charles Darwin, in the diary which he kept during the voyage of the *Beagle*, records that one evening in December 1833, when the vessel was ten miles out from the coast of Argentina, it was surrounded by enormous numbers of butterflies similar in appearance to the European clouded yellow, flying in bands or flocks of countless myriads extending as far as the eye could range. Even by the aid of the telescope it was not possible to see a space free from them, and it was estimated that the concourse was not less than a mile in width, several miles in length, and two hundred yards in height. Whither they were travelling was a matter of conjecture; but Darwin adds that "the day had been fine and calm, and the one previous to it equally so, with light and variable airs. Hence we cannot suppose that the insects were blown off the land, but we must conclude that they voluntarily took flight."

Certain exceptionally vigorous and adventurous butterflies have become almost cosmopolitan in their range. Among these is the painted lady which is at home in almost all quarters of the globe where butterflies can survive, except South America, where its place is taken by a near relative. One of its main strongholds is in North Africa, whence large numbers disperse each year to other countries, some of them frequently reaching Britain during May and June. These immigrants, by depositing their eggs on thistles, become the parents of a brood which makes its appearance in August and September of the same year. But although the British-born females of this generation lay eggs, few if any of their caterpillar progeny are able to complete their development before the onset of our winter; so that if it were not for the annual influx of visitors from abroad

the painted lady would either be a great rarity in these Islands, or else disappear altogether from the British list.

The red admiral also ranges widely over the northern parts of the Eastern Hemisphere and North America, and like the painted lady comes to us as an irregular immigrant. In most years a few adults go into hiding in the autumn and manage to survive our frosts, but the majority perish. Two other butterflies unable to maintain themselves in Britain as indigenous stocks are the common and the pale clouded yellows, which abound throughout Europe, North Africa and a great part of Asia. In some years a considerable number of individuals—especially of the common species—reach our shores in the spring, and if the season should prove favourable their offspring may appear in the south of England during the late summer; yet practically all of these are killed off during the ensuing winter.

The large and small garden white butterflies, though firmly established as British natives and well able to hold their own are frequently reinforced by flocks of migrants from the Continent so numerous that they look like “oncoming snowstorms” as they approach our eastern coast.

A few species of butterfly are known to migrate annually along definite courses, and to have extended their range in historic times. The most notable of these is the milkweed, monarch or black-veined brown which, although it finds its way sometimes to Britain, and wanders widely in tropical and sub-tropical areas, is a permanent resident only in the United States, Central and South. In the summer season it journeys northward into Canada in search of food-plants for its young, a succession of broods being maintained throughout the year. At the approach of winter the butterflies of the latest generation congregate in flocks and commence their southward journey, resting at night among herbage and the branches of trees. Those that fail to join in this withdrawal to warmer climes do not hibernate but are killed by the cold.

Other kinds of insects, including beetles, bugs and dragonflies have been observed to make migratory excursions. W. H. Hudson has described the periodic swarms of large dragonflies, that pass over Patagonia and the pampas, flying in advance of—not blown by—the *pampero*, the prevailing south-west wind

of the district. In the Eastern Hemisphere a number of the darter dragon-flies, with powerful wing-muscles, can and do make extensive migratory flights, several of the rarer species which occur in Britain being mostly visitors from across the sea. The four-spot darter is a notorious wanderer, and swarms fly to us fairly frequently from the Continent and augment the numbers of our home-bred stock.

In some years, usually when aphides or green-fly are excessively abundant, enormous swarms of the commoner ladybirds fly to us from the Continent, many of those which fail to make the passage being washed up by the waves, sometimes literally in millions, along our south-eastern shores. The still more numerous survivors pursue their journey inland to the hop-fields and market gardens of Kent, Sussex and Surrey, where they and their larvae do good service by clearing the plants of the pests which threaten to smother them. On several occasions in the past these migrants have spread to London, alighting on the roadways, pavements and walls in sufficient numbers to cause general remark.

Some gregarious insects with feeble powers of flight are often carried willynilly by the wind from one district or country to another. Aphides or green-fly are the outstanding example of this mode of dispersal. An extraordinary instance relates to the spruce aphid, of which large numbers, together with a contingent of the particular hover-fly which preys upon them, appeared on the ice-cap in Spitsbergen, eight hundred miles in a straight line from the Kola Peninsula of Northern Russia—the nearest part of the mainland where the host-tree of this species grows.

Locusts become gregarious only when they are forced by circumstances to migrate to areas where they are not indigenous. At such times, countries which have known no locusts for a long period may suddenly be invaded by immense numbers, which devastate the land for several successive years, and then die out completely. The fact that these inroads occur at irregular intervals indicates that they are caused mainly by over-population of the normal breeding places, or "outbreak areas", as they have been called. Exceptionally hot and dry seasons reduce the number of spots suitable for egg-laying by the females; and in these circumstances it has been found that the egg-clusters are deposited in the soil close together, so that overcrowding of the rising

generation results. This, in conjunction with other factors still to be investigated, causes remarkable changes in the colour, structure and habits of the insects, while instincts long in abeyance are evoked, and swarms set forth along the same routes followed by their ancestors, perhaps a decade or more previously.

The numbers which make up these migratory swarms and the damage of which they are capable may be gathered from the following statement by Dr. D. L. Gunn: "During a plague, it is common to have reports of the desert locust swarms covering areas of two to five square miles and probably of about this density; and swarms of 100 square miles or more are reported from time to time. That is to say, swarms of 1,000 tons are probably not uncommon, and they may occasionally weigh 50,000 tons or more. Locusts consume about ten times their final weight while growing up, so a 1,000-ton swarm has probably eaten about 10,000 tons of vegetation. It has been calculated that a migrating swarm of 1,000 tons will require as many calories of energy per day as 100,000 men, and requires to eat its own weight of vegetation daily."

Locusts in their journeyings seem to rely more upon favourable air-currents than upon their wing-power. They have been observed to make trial flights, as if to ascertain the direction of the wind; and when this is satisfactory the whole swarm rises and is carried forward without much effort. But the migratory instinct in some species asserts itself in the young before the wings are developed, and these hoppers—or "voetgangers" as they were called by the Dutch in South Africa—set forth on their travels afoot.

Graphic accounts have been given by eye-witnesses of the manner in which these intrepid youngsters cross streams and rivers which bar their progress. The leading files plunge boldly into the water, or are pushed into it by those following behind, and by holding on to each other or to any floating objects that may be encountered, they eventually form a living bridge from bank to bank. Surprisingly few are drowned, because the insects are continually clambering over one another, so that the same individual does not long remain submerged. Moreover, locusts are exceedingly tenacious of life, and many of those that seem lifeless when cast ashore soon revive in the sun's rays.

Some temporary associations of insects are the direct outcome of the parent's egg-laying, as in the case of certain galls, such as the common oak-apple, which houses a whole family of grubs, each in its separate cell and nourished with sap at the expense of the tree. With her delicate ovipositor the female gall-wasp inserts about thirty translucent, pear-shaped eggs into the selected bud during the winter and the gall appears with the young leaves at the end of April or early in May. In addition to its rightful tenants it usually harbours a number of intruders—unbidden guests for the most part, sharing the shelter and taking a toll of the food, but without malignant intent. Also, a few bare-faced parasites and killers are likely to force an entrance into this microcosm, threatening its premature dissolution.

Successive generations of certain wood-feeding larvae often inhabit an invaded tree for many years until it succumbs to their ravages, those of the goat moth well exemplifying this kind of gregariousness. Eggs are laid by the female moth in crevices of the bark, into which the infant caterpillars at first burrow, later penetrating the solid wood, and eventually forming a labyrinth of tunnels in which they live for a period of three years or more. The full-grown caterpillar occasionally leaves its home tree and wanders about, sometimes never to return. More often, however, it constructs—just inside the entrance to a tunnel—a bulky cocoon of chips and debris fixed together and lined with silk, in which it pupates. The adult moths are very inactive, much more given to creeping than to making use of their wings, and the females frequently lay their eggs on the selfsame tree from which they have just emerged, although some may fly at night to other trees growing in the vicinity. Thus, unless a stricken tree is destroyed, it remains a breeding centre of the pest and a menace to the neighbourhood.

The parental activities of the bark-beetles will engage our attention in the next chapter. Of their larvae, which live in burrows between the cortex and wood of various trees, it may be said at once that although their tunnels are very close together and evenly spaced they never coalesce or intersect. Like most other gregarious insects these grubs attend strictly to their own affairs, instinctively avoiding contact, and neither helping nor hindering one another.

Aphides or green-fly form closely packed colonies on the plants which they infest, especially near the growing-points and at the nodes where the leaves are attached to the stems—these being the parts where the flow of sap is most readily tapped. By viviparous reproduction they increase rapidly in numbers during the summer months, and sooner or later winged individuals appear which fly to other plants where they found fresh settlements, while in the autumn these immigrants lay the eggs that give rise to the next season's infestations.

The common cockroach—the “blackbeetle” of our basements—and the house-cricket live gregariously, the old and young of both sexes hiding together by day in family parties under floorboards, behind wainscoting and in cracks and crannies of masonry, coming out after dark to forage. They also migrate in company; and during the summer months crickets sometimes form temporary colonies on outdoor rubbish dumps.

Vast populations of insects, particularly beetles, are apt to develop in stored goods, especially cereals and flour. Corn and rice weevils are notorious in this respect, and in the past cargoes of grain carried in sailing ships have arrived at their destination swarming with these pests. The female lays one egg only in each grain, upon the contents of which the resulting grub feeds, eventually changing to the pupa within the empty husk. Strangely enough—although the distribution of the two species appears to be co-extensive—the rice weevil has well-developed wings, whereas the corn weevil has none. The bread or paste beetle works in much the same way when it chances to invade corn, but it attacks also a great variety of other food-stuffs and condiments, including capsicum and ginger. Flour in bulk is peculiarly attractive as a breeding-ground to certain moths and still more beetles. Of the latter the largest are the parents of the well-known mealworms, which are difficult to exterminate in granaries and mills, where they sometimes do considerable mischief. The fact that these larvae are much in demand as food for certain captive beasts and birds may account for the survival of the species in spite of persistent persecution. They are the progeny of two distinct strains, both equally common and very much alike, except to the eye of the expert. A much smaller but far more troublesome insect is the cosmopolitan flour beetle, whose

country of origin is unknown, not to mention several members of other genera which are scarcely less injurious.

Investigation into the economy of some of these insect populations by R. N. Chapman and others suggests that the risk of overcrowding and consequent under-nourishment is obviated by the operation of two opposing tendencies. In the case of the flour beetle, for example, it has been shown that an increase in the number of adults tends at first to slow down the rate of reproduction, because these insects have the habit of eating their own eggs when they come across them. Later, as the number continues to increase more frequent mating is stimulated, resulting in the production of a sufficiency of eggs to compensate for those which are destroyed. In this way a balance is maintained which secures the requisite nutriment for the largest number of individuals proportionate to the amount of food available.

On the generally accepted principle that numbers promote safety we may assume that a tendency to gregariousness among easily seen and well-protected insects must be to their advantage. If, for example, the spininess of a solitary *Vanessid* caterpillar, such as that of the peacock butterfly, serves to ward off the attacks of hungry birds, how much more effectively will a cluster of them, numbering perhaps several score, repel aggression. The same argument clearly applies to those species whose inedibility is advertised by their showy or "warning" liveries. An easily verifiable case in point is that of the large white butterfly's caterpillars, in some seasons exasperatingly plentiful in our gardens on cabbages and the common *Tropaeolum* or Indian nasturtium. Conspicuously marked with numerous black spots on a greenish or yellowish ground they rest habitually in serried rows on the upper surface of the leaves; whereas those of their near relation, the small white, although much less easily seen, being almost wholly green, lurk out of sight beneath the foliage. A similar instance is afforded by the orange-and-black-banded caterpillars of the cinnabar moth, bevy of which may often be seen during July and August sunning themselves on the ragwort's flower-heads. Still more spectacular are the mass displays staged by the scarlet-and-black fire-bug; but this insect, though common in the Channel Islands and on the Continent, occurs in Britain only in a few coastal areas of south-west England.

Some gregarious caterpillars live for at least a part of their lives in webs or "tents" which seem to serve primarily as a protection from the inclemencies of the weather, although they may also ward off the attacks of enemies. Those, for instance, of the small ermine moths are so diaphanous in texture that the inmates are plainly visible; yet it would be an uncommonly intrepid bird that succeeded in picking them out of the silken tangle. Also, they are effectively guarded from the minute ichneumon parasites which would otherwise pester them. The caterpillars of the common lackey moth set about weaving their retreat almost as soon as they vacate the egg-shells in late spring, and thereafter continue to enlarge it—or else make another—until they are half-grown, when they usually disperse. The broods of young brown-tail moths which hatch in September unite their infantile efforts to construct specially tough-walled shelters in which they pass the winter, huddled together for warmth, but occasionally creeping forth on exceptionally mild days to bask for an hour or two in the sun's rays. With the return of spring they still retain their gregarious tent-dwelling habit; but as they continue to feed and grow they find it convenient to separate into two or three groups, each of which sets to work and weaves a tent of its own.

Several of our native butterflies are inveterate web-spinners in their caterpillar state, notably the three small fritillaries without silvery markings on the underside of their hind-wings, of which the marsh fritillary is the most widely distributed. Since all these pass the winter as larvae their tents may be of use in repelling cold and damp; but, as Dr. E. B. Ford has pointed out, they can hardly be spun for concealment, because their makers frequently sun themselves on them, and are then plainly visible as a black, spiny mass "which is the more evident for its background of whitish silk". Moreover, these caterpillars have developed a curious habit of jerking their heads upward simultaneously when alarmed by a movement in their vicinity—a warning gesture calculated to scare away any small bird intending to molest them.

The two European processionary caterpillars have remarkably developed social instincts which doubtless redound to the safety of the community. Both kinds are active only during the

hours of darkness, spending the daytime in their elaborately woven shelters. The habits of the species whose food-tree is the oak have been closely studied by Fabre and others. The insects leave their tent at sundown and march to their feeding-ground—which may be at some distance—in a wedge-shaped formation, each family party consisting of several hundreds of individuals. The leader was formerly said to be a specially chosen or self-appointed chief: more probably this function devolves automatically on the one that first sets forth. At any rate, the pioneer seems to emit a silken thread to which the leaders of succeeding files attach threads of their own, thus bringing the whole column into unison.

The processionary caterpillars of the fir also live communally in tents and have similar habits, save that their nocturnal journeyings are made in single file with heads and tails in such close contact that the appearance of a single worm-like organism, fifteen or twenty feet in length, is produced. Some of these social caterpillars keep together as a family party to the end of their feeding period, and then spin their cocoons inside their tent.

Completely social species apart, it has been claimed that the web-weaving caterpillars are the only co-operative insects. This, however, is not quite correct, since—as we shall see later—certain beetles labour together for the benefit of their progeny.

Then there are the curious insects known as “web-spinners” that weave and inhabit silken tunnels, usually under stones or the loose bark of trees. Found mostly in the warmer regions of the globe, only two or three species occur in southern Europe and none at all in Britain. They have been described as “semi-social” and are probably related to the termites or white ants. But although a small number of adults and young live together in the same system of tunnels, which they presumably repair and extend, there is no neuter caste, and no real community life has been developed. Oddly enough, the silk glands—which are present in individuals of both sexes and all ages—are situated in the inflated first joints of the forefeet, not behind the mouth, as is the case with caterpillars.

Certain insects habitually assemble in sheltered situations when preparing for hibernation. Small tortoiseshell butterflies—like queen wasps—frequently enter dwelling-houses to roost

in crevices of the woodwork, behind pictures and furniture, or in the folds of curtains. Peacocks more often choose a wood-pile or the hollow of a tree for their dormitory. The herald moth—so-called because it has the reputation of being the earliest harbinger of spring—favours the beams and rafters of old stables, outhouses and tool-sheds, where sometimes as many as a dozen may be seen sitting motionless and close together from late September to early April. Another common and equally sociable moth—the mouse—prefers to creep under the loose bark of willows and other trees. When disturbed it makes no attempt to fly, but runs or scuttles about—a habit which, in conjunction with its drab colouring, accounts for its colloquial name.

Ladybirds—especially the two-spot species—may frequently be found during the winter in companies of fifty or more under bark or in the dark corner of an attic, the same spot being resorted to again and again by successive generations, year after year. Similarly, the cluster-fly has the habit of congregating, often in large numbers, when the temperature falls below 50° F., its favourite retreats being the disused upper rooms of houses and the roof timbers of churches. Another insect which may be called the autumn house-fly also winters in large numbers in buildings under similar conditions, often in company with the cluster-fly. It resembles the common house-fly in appearance and is apt to be mistaken for it: but the latter has quite different habits, and does not congregate for hibernation.

A tendency to gregariousness, coupled with what has been called “the homing instinct”, has been observed among other insects besides those which hibernate. An example is the large and not uncommon moth known as the “old lady”, which will return morning after morning, just before sunrise, to the identical dark corner in some shed or attic that it has chosen for its diurnal sleeping-quarters. Not infrequently several of them congregate as an overlapping cluster in the same place, to which they are presumably guided by their sense of smell rather than by sight.

Chapter Three

INSECTS AS PARENTS

IN the previous chapter we have seen that insects of various kinds differing widely in affinity are naturally gregarious or become so under certain conditions, and in some instances engage in co-operative activities. It is possible, though perhaps not probable, that the intensive development of these traits may have led through protracted evolution to the formation of true social communities, as seems to have happened among mammalian animals. Dr. A. D. Imms has pointed out that "gregarious and social insects have this much in common, the individuals have learned to tolerate the close presence in a limited space of other members of their species". But although the acquisition of this lesson suggests the incipience of a clannish instinct, the realization of a completely communal life demands that parent and offspring should live and work together: in other words, this mode of existence is possible only when the female lives long enough to associate with her progeny.

The parental instinct among insects finds expression in many different ways. In the vast majority of instances little more is effected than the laying of the eggs in situations where the young, when they hatch, will be supplied with appropriate food. This, however, frequently necessitates a remarkable display of innate prescience—as, for example, when the brimstone butterfly selects for the purpose the bursting buds of a buckthorn bush, or when the horse bot-fly attaches hers to the hairs clothing the breast and forelegs of the horse, in whose stomach the resulting larvae are destined to feed as gregarious parasites.

Some insects are at pains to guard or protect their eggs from possible danger. Often they are hidden in a crack or cranny, or fixed out of sight on the underside of a leaf; or, again, they may be inserted by means of a tool-like ovipositor into the tissues of a twig, or even into the solid wood of a tree's trunk. Occasionally they are provided with a protective disguise: e.g. the gold-tail moth covers them with a thatching of hairs detached by the

hind-legs from her brush-like tail-tuft. Cockroaches and mantids or praying insects pack them, a number at a time, into cunningly contrived pods or capsules, which are subsequently concealed in a safe place, or else fixed to a stone or the stem of a plant. During the breeding season, the males of certain American freshwater bugs carry a load of eggs on their broad backs, where they are cemented by the females.

The shield-bug of the birch—a common British species—after laying a batch of from thirty to forty eggs on the underside of a leaf mounts guard over them for a period of three weeks; and when the young hatch the mother shelters them in much the same way that a hen shelters her chicks, until they are old enough to disperse and shift for themselves.

The maternal solicitude of the common earwig is even more striking. It was first described in detail in the latter part of the eighteenth century by Baron Charles de Geer, a contemporary and for a time a pupil of the great systemarist Linnaeus. Pairing takes place in September. Throughout the late autumn and the early part of the winter the couples live together in little chambers excavated in the soil, frequently under the shelter of a stone. But in February, when the eggs are laid, the male either deserts his mate, or she drives him away. Thereafter her care for the eggs is unremitting. If they are disturbed, she quickly gathers them again into a compact heap, over which she broods. At intervals she carefully takes them one by one in her mouth, and licks them all over; and it has been found that without this constant attention they fail to hatch.

Investigations by the German entomologist Weyrauch have shown that these activities are governed by an integration of the tactile and olfactory senses. She can be duped momentarily into accepting tiny stones or smooth pellets of paraffin wax of appropriate size, but rejects them on finding that they lack the characteristic smell. Injured or addled eggs are eagerly eaten, but never those that retain their vitality.

When the eggs hatch, usually early in March, the young remain with their mother, sheltered under her body, until after their second moult. They then wander off to lead independent lives. Nothing seems to be known about their food during this period of infancy, except that they eat their cast-off skins!

The beginnings of family life are also discernible in the parental behaviour of certain beetles, namely, the bark-beetles—with their congeners the pin-hole borers or ambrosia-beetles; the dung-beetles; and the sexton- or burying-beetles.

As their name suggests, most of the bark-beetles burrow either in, or immediately beneath, the cortex or rind of trees. Some, however, go deeper, while others bore directly into the sap-wood, but the heart-wood is rarely penetrated. The members of some genera are monogamous, of others polygamous. Of the former the female usually takes the initiative. After hibernation, she scoops out a small chamber in the bark of the chosen tree, then goes for a short flight and returns with a mate. Pairing then takes place either in, or close to, the prepared retreat; after which the female sets to work in earnest, drilling a long, straight tunnel between the bark and the wood, and depositing her eggs along it to right and left alternately. Sometimes the male remains with her, but does not share in the work. When the larvae or grubs hatch, each eats its way outwards at an angle to the “mother gallery”, and when full-fed change to pupae at the end of their burrows. In this way curious and intricate patterns are traced upon the surface of the wood; and it has been found that the particular angle made by the juncture of the larval burrows with the mother gallery differs in the various species, and is thus serviceable as a ready means of identification. When the period of pupation ends, the perfect beetles bore their way through the bark and escape, leaving behind them tell-tale “flight holes”.

In the case of a polygamous species it is the male that excavates the roughly circular reception chamber in which he assembles his harem of from four to six females. After mating, each of the latter constructs her own egg-tunnel. These all radiate from the nuptial chamber; and when later the grubs burrow outwards, very complicated patterns are apt to result.

The habits of the ambrosia-beetles are very different from those of the bark-beetles proper. Only a few species occur in Britain, but they are abundantly represented in tropical countries. They tunnel within the wood itself, and their presence can always be detected by their cylindrical, black workings which are about the diameter of the lead in a pencil. In some instances eggs, larvae, pupae and adults of both sexes are found together in a common

gallery. More often the female excavates special niches or cells above and below her tunnel in which the eggs are laid and the larvae live and pupate. If the species is monogamous the male may assist the female in her labours, and later mount guard at the main entrance to the tunnel—perhaps, chiefly, to keep out rivals!

These beetles do not feed directly on the wood, but on the conidia or fruit-bodies of certain fungi which grow on the walls around them, and which vary in species according to the particular beetle with which they are associated. When first noticed in 1836 by Schmidberger they were referred to by him as “a kind of ambrosia”, hence the application of this epithet to the insects concerned. Of the half-dozen British species the one known popularly as the shot-borer is most likely to attract attention, since it is a common orchard pest, its black tunnels being often evident when the branches of plum and apple trees are cut back. This is one of the species that does not scoop out lateral cubicles, or “cradles”, in which to lay the eggs, young and old living together in the tunnels during the breeding season, in which the adults also hibernate, packed closely one behind another like shots. The wingless, almost globular male is not only smaller but always much scarcer than the cylindrical female.

The ecology or intimate environmental relationships of these ambrosial beetles has not yet been fully investigated, but the facts in so far as they have been ascertained suggest that a symbiotic or mutual-benefit partnership exists between them and the fungi with which they are associated. The intestines of many wood-eating insects are inhabited by symbiotic microbes of one sort or another, without whose aid their hosts cannot digest the “hard tack” on which they feed. Ambrosial beetles seem to have no such helpmates in their food-canals. Instead, the fungi which they cultivate on the walls of their tunnels act as intermediaries, and by altering the chemical composition of the sap which they absorb from the tree render this available as food for the beetles and their grubs. The fungi appear to have lost the power of propagating themselves by spores after the usual fashion, and would probably die out were it not for the intervention of the insects, through whose excrement they are often spread. In some instances the beetles have been observed to infect new borings by conveying thither in their mouths particles of fungi from their

older workings, in much the same way that termites and leaf-cutter ants start fresh "mushroom beds" in their nests when necessary.

Some of the larger dung-beetles, whose habits have been studied and described by J. H. Fabre and others, are definitely social in their activities, although when two or more are seen rolling the same ball it would be rash to conclude that an altruistic motive inspires the helpers. More probably their secret purpose is to rob the rightful owner of his property should the opportunity occur. But the sexes of certain species are remarkably co-operative during the breeding season, which may extend over several months. A case in point is that of the minotaur or trident-bearer which frequents sandy commons in the south of England, and similar situations on the Continent. Early in the spring a deep shaft is sunk in the soil by the female, the smaller male carrying to the surface on his broad shoulders the material which she scoops away. At a later stage he collects rabbits' pellets, shreds them with his forelegs, and drops the fragments to the bottom of the shaft where his mate is now busy excavating and provisioning the cells or chambers destined to serve as nurseries for the prospective family. She kneads the stercoraceous matter into a sort of sausage about three inches in length by half an inch thick, and lays an egg in the soil near one of its ends—a separate sausage being prepared for each chamber. Thus the grubs, when they hatch, find themselves in snug quarters amply furnished with appropriate food.

The sinking of the shaft and the completion of the first chamber occupies the beetles for three or four weeks, while each additional chamber requires another ten days' labour on the average. In late May or in June, when the hardest work is finished, the male usually wanders off to die, but the female is said to remain with the young for most of their development.

The life-histories of our native sexton- or burying-beetles have been investigated by Hugh Main, who found considerable variation in the behaviour of the different species. Typically, a male and female—often several pairs—undermine the carcass of some dead bird, beast or other animal so that it sinks into the soil. Thereafter the beetles live in subterranean cavities, in tunnels leading from which the females lay their eggs. These

hatch in about five days, and the young larvae make their way to the mother, who feeds them until their first moult on regurgitated food—also, for a brief period, after each succeeding moult. At other times they batten on the buried carrion, excreting a ferment by which the flesh is liquefied and partially digested. When the larva is fully grown it burrows into the soil and by bodily contortions forms an oval-shaped cell in which it changes to the pupa.

Facts such as those which have been summarized in this and the preceding chapters appear to point to the conclusion that the communities of completely social insects have arisen through a progressive development of maternal care conjoined with a tendency to gregariousness on the part of the rising generation. In other words, it seems essential that the mother should keep in touch with her offspring until such time as they are self-supporting, and that the offspring should be instinctively restrained from deserting the chosen nesting site.

Among the Hymenoptera, the most highly specialized of which are the wasps, bees and ants, it is possible to trace some at least of the evolutionary steps which may be supposed to have led from parental solicitude in its simplest forms to the establishment of a well-organized family life. The leaf-eating larva of a saw-fly on hatching must shift entirely for itself, the responsibility of the female being limited to laying her eggs on a suitable plant. The large wood-wasps or horntails, whose grubs get their living by tunnelling in the trunks of conifers, must needs bore through the bark with their auger-like ovipositors, a single egg being laid at the far end of the hole thus formed. Most of the parasitic ichneumons insert their eggs under the skin of their victims, but some carry them about until they hatch, only then placing them upon the caterpillar or other insect that is to serve the grub as food.

The gap separating the habits of the ichneumons from those of the huntress-wasps proper is to some extent bridged by the "beetle-killers", many of which are exceptionally large and powerful, ranking among the giants of their kind. The females, which in general are bulkier in build than the males, dig in search of burrowing grubs belonging to the chafer-beetle fraternity, and having found one first paralyse it with their sting, then place an

egg on the under surface of its thorax, usually just behind the third pair of legs. The wasp's offspring, when it hatches, bites a hole through the unfortunate grub's skin and makes a protracted meal of the contents; at the end of which it is ready to spin its cocoon and change to the pupa. The matrons of one species, whose behaviour was studied by the Italian entomologist Passerini as long ago as the middle of last century, unerringly locate the fat grubs of the rhinoceros-beetle ensconced deep in heaps of spent tan or leaf-mould. One must suppose them to be vested with a special sense similar to that which enables the *Rhyssa ichneumon* to detect the whereabouts of the horntail's larva through an inch or more of solid timber.

Females of the huntress-wasps prepare cells for the accommodation of their young, stocking each with captured prey, on or close to which the egg is laid. Many of them are termed "fossors" or "diggers" because they make their nurseries in the ground, though not a few drive tunnels in decaying timber and the pith of bramble stems, or make use of existing crevices. There are two families, namely, the *Pompilidae* and the *Sphegidae*; and it has been pointed out that whereas the former, when at work, generally use only their feet and the coxal joints of their legs the latter rely almost entirely on their powerful jaws for dislodging and carrying away the particles of soil. The Pompilids are known popularly as "spider-killers", since with few exceptions they provision their cells with these creatures, which they capture and paralyse with surprising intrepidity and skill. The Sphegids, on the other hand, commonly store caterpillars, though some take two-winged flies, grasshoppers, beetles, aphides, etc., for the purpose. As a rule, each species specializes in one kind of prey, which is not actually killed, but rendered quiescent by a deft stinging of one or more of its chief ganglia or nerve-centres. In this way two ends are served: the victim is unable to struggle while it is being dragged or carried to the nidus, or to escape when it has been deposited therein, while the carnivorous wasp-grub is provided with a supply of untainted meat for its consumption.

The largest and most characteristic of our British Sphegids are the sand-loving wasps, of which there are four native species, black with most of the waist and the fore-part of the abdomen

red. The habits of the two commonest have been closely studied by O. H. Latter and others. They are indefatigable workers, and as only one cell is excavated at the end of each shaft a fresh one has to be sunk for every egg that is laid. Both are punctilious in covering the entrance—usually with a small, flat stone; while its whereabouts is further concealed by smoothing down the surface soil, perhaps also by cutting and scattering about the area a few short lengths of roots or sun-dried grass.

In the matter of provisioning, however, the behaviour of the two species is very different. The red-banded sand-wasp supplies her offspring with two large caterpillars apiece, and thereafter takes no further interest in their welfare; whereas the heath sand-wasp captures and stores only a few small caterpillars to start with, returning again and again to the cell during a period of several days following the hatching of the egg, and on each occasion bringing fresh supplies for the growing youngster. In this instance (to quote Mr. Latter) “we find the beginning of the idea of a more permanent nest, of attachment to a particular spot, and of a lasting maternal solicitude. It is interesting also to note that frequently a number of individuals of this species will nest side by side in the same small patch of ground. Such an association renders it conceivable that the neighbours may help one another, but here direct evidence is wanting.”

Very different are the huntress-wasps of the genus *Cerceris* which store beetles in their brood-cells. With their stockier build and black-and-yellow banded bodies their appearance is far more wasp-like in the orthodox sense of the term. The females of several species have been seen to carry off some of the weevils that work mischief in our orchards and gardens. The victims are paralysed by stinging through the membraneous joints of their armour, usually between the thorax and abdomen. Exactly how the wasp's grub manages to extract the nutrient content from its shelly envelope is uncertain. Frederick Smith, an eminent entomologist of last century, stated that the egg does not hatch until some days after the prey has been deposited in the cell, so that the dampness of the soil, acting upon its hard exterior, renders this sufficiently soft to be gnawed through by the grub; but this does not seem to have been corroborated by any more recent observer.

A black-and-yellow livery is also sported by some diggers of the allied genus *Crabro*, though a number of its members are entirely black. Most of these wasps store two-winged flies of various sorts as provender for their young. Certain of the larger species hunt game more bulky than themselves, such as crane-flies, blow-flies and hover-flies; the smaller prey on gnats and midges, while the tiniest collect green-fly or aphides. Another small group is known as frog hopper wasps because its matrons drag the sedentary nymphs of these insects from the blobs of "cuckoo-spit" which they secrete as a protective covering.

The "swift-darter" wasps are small, dark-coloured insects with a singular resemblance to the two-winged flies that they capture as provision for their nests. The commonest may often be seen in considerable numbers during July and August visiting for their own delectation flowers whose nectar is easily accessible. This species is about a quarter of an inch in length, black, with several pale spots along the sides of the abdomen and a covering of silvery hairs on its face. In her habits and movements the female is deceptively fly-like. "She sits basking on the bare stones (writes O. H. Latter) in the way that flies so often do, she flies in a very similar way, turns her silvery face towards the observer, or towards a fly that happens to alight close by. All these resemblances to a fly seem to have a purpose . . . thanks to her disguise she is able to pass and even play among the flies without arousing suspicion. She affords us one of the very few examples of what is termed 'aggressive resemblance'. Her main object in life is to secure as many flies as possible with a minimum of trouble. Her burrow is about three inches deep, and is always placed close by or even in a patch of bare soil where flies may bask; but she disdains the 'sitting' shot, and invariably catches her prey in mid-air, swooping on it like some tiny falcon."

The field digger-wasp—another black-and-yellow banded species—also provisions its cells with two-winged flies, but in this instance the females resort chiefly to the droppings of cattle to make their captures. Frederick Smith gives an amusing account of the methods which they employ. They do not swoop or dart upon their prey from the air, but walk about among the flies in a sort of innocent, unconcerned way, awaiting an opportunity to seize one of them unobtrusively without alarming the rest.

Sometimes, however, if the flies are exceptionally active or wary they lie motionless and feign death until the chance occurs to pounce upon a victim, when they suddenly become as "active as any puss".

The slender black borer, with its long, thin waist, resembles in build the sand-loving wasps described in an earlier paragraph, but is much smaller, and lacks their characteristic red banding. It rarely makes tunnels of its own, but usually nests in the deserted burrows drilled in decaying wood by the larvae of beetles, in the tubular hollows of reeds and straws, or in the stems of bramble or other plants from which the pith has been cleared. The cells are separated from one another by strong partitions of mud or concrete, the entrance to the tube being sealed with a considerable quantity of the same material. The wasps of this genus differ from almost all other Sphegids, but resemble the Pompilids, in stocking their cells with spiders.

Although less disposed to gregariousness than some of the solitary wasps already mentioned, matrons of the genus *Bembex* certainly excel in the care which they devote to the welfare of their progeny. These huntress-wasps, no examples of which occur in Britain, feed their young on two-winged flies, only one of which is placed in each cell when the egg is laid. Afterwards, when the grub has consumed this initial ration, more are brought to it day by day until it is replete and begins to spin the cocoon in which it changes to the pupa. This behaviour clearly involves the capacity on the part of the mother to memorize with no little exactness the location of the nest, since in order to capture suitable prey she often ranges far and wide, returning, it may be, only after a long interval. That she comes back unerringly again and again to the exact spot is all the more wonderful since the entrance to the burrow, which is usually made in loose sand, is quickly effaced by drifting particles and needs to be swept clear at each visit.

"During almost a fortnight (says Fabre), while the larva is growing, the meals follow each other thus, one by one, as it needs them, and so much the nearer together as the nursling grows stronger. Towards the end of the fortnight the mother requires all her activity to supply the glutton's appetite as it crawls heavily amid the remains of its repasts—wings, feet and horny

rings of abdomens. Each moment she returns with a new capture or comes forth for the chase. In short, the *Bembex* brings up her family from hand to mouth without storing provisions, like the bird which brings a beakful of food to the little ones in the nest."

In the case of a common southern European species specially watched by Fabre a total of from fifty to eighty "heads of game" is needed to satisfy the requirement of the grub—the majority of them large, blood-sucking gad-flies. Whether more than one nursery is catered for at the same time, and how many larvae are reared by each female during the season, are questions which still await answers.

The true wasps as distinct from the huntress-wasps, may be recognized by the lengthwise folding of the fore-wings when they are not in use, the hinder half being doubled under the front half. This is characteristic of the whole family, which is divided into two sub-families, namely, the solitaries and the socials—the latter comprising the "wasps" of popular parlance, which will be dealt with in the next chapter. The solitary wasps are smallish insects, banded and marked with yellow on a black ground and if examined in detail may be distinguished by their toothed or bifid claws. In general, their habits resemble those of the huntress-wasps described above, each female building and provisioning her nest-cells without assistance, even when a number of individuals are working close together; nor are there any records of food being brought periodically to the developing brood.

These little wasps are highly skilled artisans and builders, while some are accomplished masons. It is often stated that—like house-martins—they use mud when constructing their cells; but some, at least, employ particles of dry soil worked up with their saliva into a kind of concrete. The British heath potter-wasp uses this material to fashion its more or less globular cells which are usually attached to the twigs of heather, or some other low-growing plant, though occasionally they are built on the vertical surface of a stump or post, when they take the form of a hump or dome.

Our fifteen native species of the allied genus *Odynerus* make their nurseries in a variety of situations. One—the spiny mason-wasp—burrows in banks, usually of rather stiff soil, and adds to

the entrance hole a projecting, downwardly directed spout, which may serve to keep out would-be intruders, such as the pretty parasitic ruby-wasps and certain two-winged flies of malign intent. Some make excavations in the pith of dead bramble stems and line the tunnels with a coating of fine sand, while others have been known to build their cells in door-locks, or in the hollows of such objects as cotton-spools and blind-tassels. One enterprising individual actually made her nest in the barrel of an old pistol that had been left lying in an outhouse ! All stock their cells with tiny caterpillars, which they paralyse by stinging, after the manner of the huntress-wasps.

The great bee family is represented in Britain by not far short of 250 species, the majority solitary in their habits. Unlike wasps, which—as we have seen—feed their young on captured insects or spiders, bees are strictly vegetarian, rearing their progeny on a mixture of honey and pollen. As their scientific name proclaims, they are without exception “flower lovers”, and in virtue of this proclivity have certain characteristics that distinguish them from all other members of the Hymenopterous Order, to which they belong. If we examine a bee’s hairs under the microscope, we shall find that at least some of them are minutely branched, or plumose. That these specialized hairs are of value in that they entangle and hold pollen cannot be doubted, although this may not be their sole function, seeing that they are possessed not only by the females and neuters, but also by the males and cuckoo-parasites, neither of which gather pollen. Typical female and neuter bees may also be known by an enlargement of the basal joint of the hind tarsus or “foot”, which is known as the metatarsus or planta, and in many instances is as broad as the tibia to which it is articulated. It often plays an important part in the work of pollen gathering, stiff hairs on its inner surface serving to rake or brush the grains from the hairs of the body. Later, by a crossing of the legs during flight, they are transferred to the corbicula or “pollen baskets”, as the depressions on the outer surfaces of the metatarsi are called. But different kinds of bees gather and carry home their pollen in different ways. Indeed, the appliances and methods employed are so varied, and in many instances so little understood, that they present a wide field for investigation and discovery.

Bees fall naturally into three main groups according to the length and shape of the mouth-part which may be termed the proboscis or "tongue". There are three chief types of tongue, namely: (1) short and forked, (2) short and pointed and (3) long and ribbon-like, tapering gradually to a point, which may carry a tiny concave "spoon", serviceable for extracting nectar from the far end of a floral tube.

Of bees with short forked or bifid tongues we have about a score of native species, some of which occur in large numbers during the summer months, when they may be seen visiting the flowers of spurge, ragwort, mignonette, stonecrop and other plants whose nectar is easily accessible. They are grouped in two genera, one known as *Prosopis*, in reference to the white markings on the face of the males, the other *Colletes* because their cells are lined with a gluey substance called "propolis" collected from the buds of trees. Prosopids are small, black, almost hairless insects that emit a peculiar but agreeable scent if handled. They are probably the most primitive of all existing bees, their relationship to the hive-bee having been likened to that of the cave-men to the dwellers in our modern cities. For the most part their females nest in plant-stems, with a special fondness for burrowing in the pith of bramble stems from which the ends have been cut off, lining their cells with a secretion from the mouth which sets as a waterproof coating through which the semi-liquid food-store cannot percolate.

The Colletids, of which there are six or seven British species, are clothed with brown hairs on the head and thorax, with close-set whitish bands encircling the abdomen. They are most noticeable during July and August, when large colonies of them may frequently be seen busily at work excavating their burrows close together in the same bank—amicably, though without co-operation.

British bees with short, pointed tongues total more than one hundred and twenty kinds—by far the largest section of our solitary species. They are often referred to collectively as "mining bees" because the majority are inveterate diggers in the soil, whether the surface is loose and sandy, hard-trodden clay or gravel, or a compact turf. They are grouped by specialists in about ten genera, those comprising the most typical examples being *Andrena* and *Halictus*. A preponderance of the species

resemble small honey-bees in general appearance, but a few are more showily coloured. One of the commonest of the latter is the reddish-brown lawn-bee, which in some districts abounds in gardens, where it attracts attention by throwing out little craters of fine soil round the mouths of its workings. The first females of the season usually make their appearance during April, and after mating sink their shafts from six to twelve inches deep in the earth, from the sides of which the nursery-cells are excavated. These are provisioned with the usual mixture of pollen and honey, and in each an egg is laid. The larva is full-grown about midsummer, when it changes to the pupa ; but although the final skin-changing takes place in the late summer or early autumn, the perfect insect lies dormant in its underground cell until the spring of the following year.

Related to the Andrenids is the hairy-legged mining-bee which has the reputation of being the most beautiful of all our solitary species. The head and thorax are clothed with a pale, yellowish-brown pubescence, the abdomen is conspicuously belted with white, while the hind-legs of the female are thickly set with bunches of bright golden, plumose hairs—which enable the insect to carry loads of pollen equal to half her own weight.

This bee nests in sandy places, usually near the coast, and its method of work has been studied and described by Hermann Müller. The vertical shaft may extend into the ground to a depth of from one to two feet, the particles of soil being first loosened by the mandibles, then thrown backwards under the body by the fore-legs and thrust to the surface, where each load is deftly scattered over a wide area surrounding the entrance-hole. About six nursery-cells or brood-chambers are excavated along the side of the shaft. The first necessitates the carrying up of more soil ; but thereafter the bee adopts the labour-saving device of using what is scooped out to form each fresh cell as material for closing up the one previously made. The egg is laid on the top of a large mass of pollen moistened with honey and supported on three short feet which are supposed “to keep it steady should the larva upset the balance by eating one-sidedly”.

Another very extensive genus of mining-bees with short, pointed tongues is *Halictus*, most members of which are moderately hairy, dark in colour, with whitish spots or narrow bands

on the abdomen. The various species appear in succession from April to October, many being double-brooded, so that they are seen both at the beginning and the end of the summer. The least mining-bee, whose head-to-tail length is about one-fifth of an inch, is said to be the smallest of all British bees. Some of these Halicti form large settlements in the same situation and are of special interest because in these colonies several females frequently collaborate to sink a common shaft from which the private burrows of the individual matrons branch off. Indeed, this particular group of bees seems in some measure to bridge the gap separating the solitary and the social species, and for this reason we shall deal more fully with their habits in a subsequent chapter.

At this point something should be said concerning the very numerous bees known as "cuckoos", because they make no nest-cells of their own, but take possession of those of other species, to which, strangely enough, they are often closely related. A large proportion of the solitary species and several of the humble-bees are harassed by these impostors, which contrive to enter and lay their eggs in the cells made and provisioned by their "hosts"—as the victims are euphemistically styled—so that the alien grub—which usually hatches first—eats up most of the food intended for the rightful inmate, the upshot being that the latter starves and dies.

The problem of the relationship of cuckoo to host and how it came about affords attractive food for speculation. In some instances the two are so much alike that a close scrutiny is needed to tell them apart, in others they are so unlike that it is difficult to discover points of resemblance. The elegantly built, almost hairless wandering cuckoos, for example, in their yellow or red-and-black liveries, present quite a wasp-like appearance. Yet although so different at first sight from the normally sombre-coloured Andrenids which they pester, they share with them so many structural similarities as to leave little room for doubt that they originated from the same ancestral stock, but in the course of evolution have fallen into reprehensible habits—though why in the process they should have had to don such gay habiliments has not been satisfactorily explained.

This view seems all the more plausible since there is evidence

which suggests that some, at least, of the cuckoo-parasites attached to the Halicti are not consistent shirkers of their parental duties, but occasionally excavate and provision nest-cells of their own. Although differing superficially, they closely resemble their hosts both structurally and in their hibernation habits; but there is no fraternizing. On the contrary, a *Sphcodes* cuckoo has been seen to attack and kill its *Halictus* host before appropriating its burrow. The conclusion seems to be either that the members of the former genus have not yet completely adopted the cuckoo mode of life, or else that they have begun to mend their former nefarious ways. Which of the alternatives is the more probable is an open question.

The most highly specialized British bees—those with long, pointed tongues—are grouped in a number of genera, the most noteworthy of which are the leaf-cutters, the masons, the humblebees and the various races and hybrids of the hive-bee, the two last-named being definitely social in their habits. Besides these mention must be made of three species of outstanding interest, namely, the wool-carder bee, the long-horned bee and the hairy-footed bee.

The wool-carder bee—black, with greyish-brown hairs and conspicuous yellow spots on the abdomen—owes its popular name to the fact that it strips the down from the stems of various plants, especially the red dead-nettle, and uses it to line the cavities in which its nest-cells are hidden—such as the interstices of door-locks, empty snail-shells, or the burrows made in wood or earth by other insects. It is said seldom, if ever, to make burrows of its own. The cells in which provision is stored and the eggs laid are made of a semi-transparent, waxy material secreted by the insect.

The long-horned bee—so-called because the antennae of the male, if turned back, reach to the tip of its abdomen—is one of our largest solitary species, robust in build and clothed with brown hairs. The females, whose antennae are of normal length, are active from May onward until the late summer, burrowing some six inches into the soil, at which depth an oval nursery cell is excavated and lined with a waterproof secretion. This species is markedly gregarious, and often forms large colonies in restricted areas where the conditions are favourable.

The hairy-footed bee is one of spring's harbingers, and is by no means uncommon in country districts. The black, yellow-legged females may be seen on sunny March and April days flying hither and thither rapidly, or visiting the early blossoms in gardens and hedgerows. The males, distinguishable by their bright brown colouring and the remarkable fringe of long, black and grey hairs on the middle pair of legs, dash about in attendance on their prospective mates, often apparently chasing them, but seldom settling to rest or feed. The site chosen for nesting is usually a bank of firm sand or dryish clay. The burrows are rather shallow, and lead to cells whose walls are made exceptionally hard by a concrete-like casing of sand or clay mixed with the bee's saliva and applied after she has provisioned them.

This is another bee that courts the society of its fellows, large numbers often associating at a congenial spot. Mr. Latter has given us a graphic word-picture of such a gathering. "Females are to be seen entering or leaving their burrows, intent on their business, or possibly engaged in a headlong flirtation with two or three males to and fro in front of the favoured bank, while dozens of males keep up a loud humming as they dash through the air."

The keenly interested observer is sure to notice a sprinkling of cuckoo-parasites mingling with the gay throng—black, white-spotted bees, slightly smaller than their hosts, and with more sharply pointed hinder-ends. But these are not the only enemies of the hairy-footed bee, which happen to be one of several nearly related species that are plagued by the infant progeny of the common oil beetle. The gist of this complicated life-story is that after hatching these minute but precocious youngsters climb to the flower-heads of various herbaceous plants. Many of them perish incontinently; but now and again a lucky one is carried by a visiting bee to her cell, where it first makes a meal of the newly laid egg, and then eats up the stored food.

Some of the leaf-cutting bees, of which there are seven or eight British species, attract attention in gardens owing to their habit of mutilating the foliage of roses and other plants, afterwards using the material thus acquired for cell-making. Their burrows are made most frequently in decaying wood, but occasionally in sound timber, or in the ground. The female alights upon

the edge of a leaf, grasping with her legs the portion that is to be detached. Then, with her mandibles, she makes a rapid, continuous cut; and just when she seems to have bitten through the last shred of her support and to be in danger of falling to the ground, her shining wings are put in motion, and darting off she carries the severed fragment gripped safely beneath her body. The cut pieces are either oblong with rounded ends or circular. The number used in making a cell varies with circumstances, but normally there are seven of the former and four of the latter. First the oblong pieces are conveyed one by one to the burrow where they are coaxed into place, one overlapping another, to form a thimble-shaped container, which is filled with a mixture of pollen and nectar, gathered chiefly from thistles and other *Compositae*. Finally an egg is laid and the cell sealed tightly with circular pieces of leaf.

Most of the leaf-cutters have their attendant cuckoo-parasites. They are also plagued by certain minute ichneumons of the family *Chalcididae* which make their way into the burrows and lay their eggs in the cocoons spun by the leaf-cutter's larvae before they change to pupae. In the sequel the ichneumon's grubs eat up the bee's pupa and complete their metamorphosis in its cocoon.

The *Osmias*—known popularly as “masons” and “carpenters”, because of their proclivities for both these occupations—are in many respects the most accomplished and versatile of all the so-called solitary bees. Very varied nesting sites are frequently selected by individuals of the same species, the separate cells—constructed of earth mixed with a glutinous saliva—being ingeniously adapted to fit the particular situation chosen, thus showing (to quote O. H. Latter) “that they are following no blind instinct, but have some power of choosing for themselves”.

Our commonest native species, the little red mason, about half an inch in length and densely clothed with yellowish-red hairs, occurs in most rural districts and—like several of the leaf-cutters—sometimes turns up in suburban gardens. The females make tunnels in decaying stumps, posts and beams, scrape out holes in the crumbling mortar of old walls, or sink shafts and burrows in sand-banks. But they prefer ready-made crevices when they can find them, and have been known quite often to

pack their cells into the interstices of door-locks when these are seldom used. In one instance fourteen cells were wedged in the tube of a flute that had been inadvertently left for a few days in a summerhouse—this interesting specimen being on exhibition at the British Museum (Natural History). Again, empty snail-shells are frequently appropriated, the cells being fitted singly into the narrow whorls but set side by side in twos or threes near the mouth, which is eventually sealed with concrete. In the case of the two-coloured *Osmia* the shells, when filled, are sometimes covered over with bits of grass-stem piled up to form a small hillock two or three inches in height and about six inches in circumference.

Other species of the same genus make their nest-tunnels in the pith of bramble stems, usually choosing those whose ends have been lopped off by the hedge-trimmer, thus saving themselves the labour of gnawing through the woody cuticle. Others, again, fix their cells to the underside of large, flat stones covering a slight hollow. The nearly related mason-bee of southern Europe which is the subject of some of J. H. Fabre's earlier essays, works with a particularly hard concrete of its own mixing. It first constructs a group of eight or nine cells, usually on the exposed surface of a large stone, then roofs them over with a thick layer of this resistant material, forming a dome-shaped structure about the size of half an orange. The vigour and pertinacity of the little artisan may be judged by the fact that the building and provisioning of each cell calls for two whole days of unremitting labour.

Chapter Four

SOCIAL WASPS AND THEIR WAYS

AMONG insects it often happens that apparently unimportant structural features are linked inexplicably with surprising differences in behaviour. We have already seen, for example, that the true wasps—typified by the marauding hordes which besiege our kitchens when jam-making is in progress—are distinguished from their numerous huntress and digger relatives by the fact that their fore-wings, when not in use, are folded lengthwise, the hind part under the front part. These *Diploptera* or “double-winged” wasps are sub-divided into two families, (1) the solitaries and (2) the socials. The former—often styled “mud-wasps”—are characterized by having only one spine on the tibia of the middle leg where it joins the tarsus, while the claws of their feet are cleft or bifid. Some details of their nesting habits were given in the preceding chapter. By contrast, the latter—the wasps of common parlance—have two tibial spines on the middle legs and their tarsal claws are undivided at the tip. It is with these, the social species, that we are now to deal.

The first question to suggest itself is, how did the complex communal instincts governing the lives of these insects originate? Although no completely satisfying answer is available we may feel fairly certain that they evolved, like the structural peculiarities referred to above, through a process of natural selection, from those of a solitary ancestry, whose females had adopted the practice of progressive provisioning—i.e. of bringing food to their offspring periodically, instead of stocking the cell with a sufficiency before laying the egg. This, as we have already noted, is done by some of the sand-wasps and by the species of *Bembex* studied by Fabre, while African wasps of the genus *Synagris* are said to chew the food into fragments before feeding it to their young, thus registering a further advance in parental solicitude. Closer contact with the rising generation seems usually to have been correlated with increased ingenuity and resourcefulness in

nest-building, plus an intensification of the homing instinct, enabling the site when chosen to be recognized unerringly.

Some tropical Eumenids construct remarkably large covered nests of paper-like material similar to that used by social species. One such is described by Dr. David Sharp as "a mass of cells encircling the branch of a tree, which therefore projects somewhat after the manner of an axle through the middle: the cells are very numerous, and are quite as regular as those of the most perfect of the combs of bees: the mass is covered with a very thick layer of paper, the nest having somewhat the external appearance of half a coconut of twice the usual size". This nest may be seen at the British Museum (Natural History). Whether it represents the labour of few or of many individuals is not certain. The gulf separating the solitary and social modes of life, however, must in the end have been bridged finally by the overlapping of successive generations, so that the mother associated with, and was helped by, her adult progeny.

Of existing social wasps the least specialized are those of the very numerous genus *Polistes*, which has an exceptionally wide geographical distribution, but—rather surprisingly—is not represented in Britain. For the most part they are black-and-yellow-banded insects of rather slender build, whose small nests of hexagonal cells, usually attached by a stalk to the twig of a bush, have no outer cover or envelope to protect the inmates from cold and damp. The common European species, known as the French *Polistes*, has been studied by a number of competent entomologists both at large and in the laboratory, so that our knowledge of its economy and habits is fairly complete. The life-history of a community begins in early May when the foundress or "queen" constructs a few shallow cells in which the initial brood of grubs is reared. These are fed and tended by their mother, and on reaching maturity prove to be sexually imperfect females termed "neuters" or "workers". Mother and offspring differ little in external appearance; but as the population of the colony increases it is possible by marking the individuals with different coloured paints to show that whereas the originating queen now remains permanently at home and does all, or almost all, the egg-laying, the workers take over the duties of foraging and feeding the young, as well as collecting material for enlarging

the nest, which at the end of the season may consist of about one hundred cells, although in regions where the summer is long and the climate favourable the number is often much higher. At the approach of autumn the queen lays a few eggs that give rise to perfectly developed females, or princesses, which—after pairing with males—lie up in hiding during the winter and start fresh colonies with the return of spring.

Among social insects (except termites) the spermatozoa received by the female from the male at the time of copulation are stored in a special sac or receptacle the opening from which into the oviduct is under her control. When she allows an egg to be fertilized by a spermatozoon it develops into a female; unfertilized it becomes a male. Whether the female attains maturity as a princess or a worker is believed to depend largely upon the manner in which the grub is fed and nurtured. On this point, however, the evidence is inconclusive. The workers are unattractive to the opposite sex, and have never been seen to mate. Most, if not all, of them are capable of laying male-producing eggs; but unless the queen should suffer an untimely death they do this only at the season's end. In the late autumn many of the grubs are killed by cold and others are dragged from their cells and dropped to the ground by their quondam nurses.

This so-called French wasp has in fact a remarkably wide range extending southward from North Germany to the Sahara. In the warmer regions, where it most abounds, several pregnant females, after hibernating, frequently unite their labours to build a nest; but when this happens one of them eventually becomes the queen regnant, the rest gradually ceasing to lay eggs and taking on the duties normally performed by workers. The successful individual seems to achieve and hold her dominant status by terrorizing the others, rushing at them with open jaws, while uttering a loud, buzzing sound, and perhaps preventing them from laying. Dr. O. W. Richards, quoting from the records of the Italian entomologist Pardi, tells us that when once her position is firmly established no more coercion is needed, the ovaries of her erstwhile rivals degenerating, either because they work harder and have less food, or because they are not allowed to lay. "Among these worker-like queens, which Pardi calls auxiliaries, there is a regular order of dominance, in

which the queen always comes first. The position of a wasp in the scale is shown most clearly in the disposition of food, but it appears also in the frequency with which it shows aggressive behaviour and lays eggs, and in the amount of time spent on the nest. A wasp high in the scale is more likely to be given food by one of its inferiors and less likely to give it away. Similar orders of precedence are known in many mammals and in birds, such as chickens, which live in groups. According to Pardi, when the first brood of workers emerges, the auxiliaries all disappear, so that they serve only to get the colony started and as far as is known never found a colony of their own."

In the oases of the Sahara, where the equable climate favours continuous breeding, this same species of wasp frequently founds fresh colonies by swarming—i.e. a queen, together with a number of workers, fly off and start building a new nest at some distance from the old one. It seems probable that these swarms are led by a young, newly mated queen, not by the old foundress queen as is the case with the hive-bee; but this is not yet certain. On the southern edge of the South American tropics, where the winter is short, whole colonies of wasps belonging to the genus *Polistes* are said to hibernate, resuming their activities with the return of warm weather. But, since in temperated regions wasps feed their young almost exclusively on insect food and never store more than an infinitesimal quantity of nectar in their cells, the life of the community is necessarily limited to the summer months.

Social wasps of the allied genus *Icaria*, which are especially numerous in tropical East Africa and the Pacific Islands, build stalked nests without covers similar to those of *Polistes*, but instead of making the combs plate-like and more or less circular they increase their size by adding cells at the end opposite the point of attachment, the result being a narrow strip or ribbon.

Generally speaking, the habits of our British social wasps, though more rigidly specialized, do not differ greatly from those of the Continental and tropical species described above, but they excel in architectural ability, their nests being wonderful symmetrical structures of pendent combs suspended one from another by stout pedicles and enveloped in an outer covering which has a single opening at its lower extremity.

We have seven native species, including the hornet, which is easily recognized by its superior size and reddish-brown and yellow colouring, the other six being black and yellow, and all very much alike to the casual observer. Hornets vary a good deal in size, but a small individual of the worker caste is always considerably larger than a queen of any of the other species. Although common in many parts of the Continent, this insect is most likely to be met with in southern England, and even here it seems to have become rarer of recent years. Its favourite nesting site is a hollow tree, failing which it will make its home among the rafters of a barn or some other building, occasionally in a hole in a bank. The material used is a papier-mâché made from fibres of rotten wood moistened with the builder's saliva and often mixed with sand. Its colour, when dry, is yellow; but although the cells of the combs are constructed with the utmost regularity, the outer cover is not always completed when the nest is built in a cavity which affords adequate protection from the elements. Hornets have the reputation of working late on warm moonlight nights.

Of our six black-and-yellow species the two most abundant are the one known as the common wasp and the equally numerous German wasp. Both these build their nests in underground holes, as also does the rufous wasp, whose yellow markings, being tinged with reddish, have almost the colour of orange-peel. The last-named is probably fairly numerous in many localities, but for some unexplained reason it seldom visits houses, even in the late summer, when the other species often make themselves unmitigated nuisances. Two others, namely the tree- or wood-wasp and the Norwegian wasp, nearly always suspend their nests in shrubs or trees, the former often in a gooseberry- or gorse-bush, the latter from a lower branch of a Scots-pine or some other conifer. The paper-like building material used by these arboreal species and by the German wasp is of a grey tint, whereas that of the common wasp is yellowish, like that of the hornet, but a shade paler, and finer in grain. Our seventh wasp, though technically ranked with the socials, is in fact a confirmed "cuckoo". It makes no home of its own and rears no workers, but lives at the expense of the rufous species, in whose nests it lays its eggs and by whose workers its grubs are reared. Exactly how the

alien establishes herself is uncertain; but she seems to come from hibernation some weeks later than her "host", and probably gets into the nest of her choice at an early stage of its construction. The rightful queen may survive for a time, but eventually she either dies or is killed by the intruder, so that at the end of the season the brood consists almost entirely of cuckoo males and princesses.

The social life and architectural methods of our native Vespid wasps—and, indeed, of all those inhabiting temperate regions—conform to much the same pattern. The details given in the following paragraphs refer mainly to observations of the common and German species made during a number of successive years by the present writer. The foundress of a community is one of those large individuals or queens, fresh from hibernation, which are among the early harbingers of spring. Her nuptials were accomplished late in the preceding summer. Thereafter, warned by the chills of autumn, she sought out a snug hiding-place, among the rafters of a barn, the thatch of a cottage, or the crease of a window-curtain, and settled herself to sleep, first folding her wings beneath her body and taking a firm grip with her jaws lest, in the oblivion of slumber, her foothold should relax. Many queens also lie up for the winter in the old nests when these have been built in especially dry and sheltered situations where they do not disintegrate quickly. As a preliminary to hibernation a large quantity of sugary food is consumed, most of which is stored in the tissues to be drawn upon during the protracted period of fasting.

Hibernating wasps can tolerate surprisingly low temperatures: in one recorded instance exposure to twenty-two degrees below freezing-point was sustained without apparent ill effects. On the other hand, unseasonable warmth, by rousing the sleepers prematurely, is often fatal. Hence, a severe winter is likely to be followed by a summer and autumn when wasps are excessively numerous, whereas after a mild one they may be noticeably scarce. In some years early warm weather at the outset of the season followed by a spell of cold and wet results in the death of many queens before they are able to start building.

After a hasty but adequate meal and a brief toilet the newly awakened queen turns her attention to the serious business of her

life. Being (as we are supposing) the scion of a species with subterranean proclivities she flies with deliberate, questing guise along hedge-banks and the escarpments of gravel pits, seeking a cavity that will satisfy her exacting notions of fitness. Not infrequently her house-hunting ends tragically. Late frost or heavy rain, the beak of a bird or the grinding heel of austere mankind—any such happening may prove an overwhelming catastrophe to the contingent queen, whose kingdom and subjects are as yet a vision of the future.

Let us assume, however, that she succeeds in finding a hole to her liking. It will be, perhaps, the deserted residence of a mouse, three or four inches in diameter at the inner extremity, and from the roof will protrude at least one substantial root—this latter requirement, for reasons that will presently appear, being indispensable. She may proceed to enlarge the cavity somewhat, tearing away small particles of soil or tiny pebbles with her mandibles and carrying them through the entrance tunnel to the open.

These preliminaries over, she flies off to obtain a supply of material for her foundations. Alighting upon a fence or some other exposed woodwork—or, failing this, upon the barkless trunk of a dead tree—she rasps off a quantity of wood-fibre and macerates it with her saliva into a kind of coarse paper—the stuff of which the prospective nest is to be fashioned. But as yet the queen has prepared only one tiny pellet—as much as she can conveniently carry in her jaws—with which she flies back to the chosen hole and there spreads the moist atom upon a small area of the root from which the fabric of the nest is destined to hang. Hour after hour, day after day, she repeats this passage to and from the source whence the raw material is obtained, always returning with a pellet of papier-mâché. In the course of a week or so the result of her labour takes the form of a little cap or hood pendent from a footstalk attached by a triangular base to the supporting root. Beneath this shelter are three or four shallow cells, each containing an egg, which—since the opening of the cell is directly downward—is glued firmly to the side.

At this stage the queen is pressed for time and does no unnecessary work. Her paramount object is to rear as quickly as may be a bevy of loyal retainers to aid her in her labours. So her

first cells are mere shallow saucers when the eggs are laid in them. Later, when the grubs hatch and begin to grow, she builds up the cell-wall round them as occasion requires—this in addition to satisfying the youngsters' daily demands for nourishment and nurture. Her flow of saliva for paper-making is not inexhaustible. She never makes more than a score of cells—frequently only half that number, much of her time being now occupied with feeding and cleaning the brood.

This state of things continues for several weeks, more or less according to the temperature. But sooner or later the initial batch of grubs comes to maturity and issues from the cells as fully fledged wasps. These are all of the worker caste—imperfectly organized females whose *raison d'être* is the performance of the community's menial labours and its protection from molestation. With their advent the queen does no more building or nursing, but devotes all her energies to egg-laying, leaving everything else to her daily increasing army of helpers. She no longer goes abroad, but they fly hither and thither over the countryside gathering food and building material; so that as the summer advances the nest and its population grow apace.

By the end of September, if circumstances have been favourable, the nest may be considerably larger than an association football. The original comb is widened and new ones to the number of six or seven are suspended by stalks or pedicles one from another, while layer after layer is removed from the inside and added to the outside of the protective envelope. Much time is also devoted to the enlargement of the cavity in which the nest hangs, the workers removing just enough earth day by day to accommodate its increasing bulk. The smaller particles are carried out bodily—a task involving much toil, since the passage leading to the open air may be tortuous and several feet in length. Stones and pebbles too heavy to be transported are undermined and allowed to gravitate to the floor below the nest. The separate cells are cleaned and used again and again for rearing successive relays of grubs; but as the community multiplies and more standing room is needed at night or in rainy weather when all need shelter the cellular structure is cut away from the under-surface of the upper comb, thus providing a commodious chamber in which the adult wasps may congregate for rest and warmth.

At the end of July a prosperous subterranean community of wasps may number several thousands of individuals, each being a direct offspring of the originating queen. It is a peculiarity of the wasps' architectural practice that although the nest is being constantly enlarged it never appears unfinished. Although, as we have seen, the sheath or envelope is cut away daily from within and added to from without, this work is so adroitly performed that the contour is always neat, shapely and perfectly closed, save for the one opening through which the inmates enter and leave. Thus, the space occupied by a wasps' nest is filled progressively twice over, first by the outer cover or envelope, then by the combs of cells. Obviously this method of enlargement necessitates a far greater expenditure of labour and material than would be called for if the structure could be planned in the first instance on a larger scale, especially as the wasps rarely, if ever, repulp their paper, once it has been moulded into shape. But to embark on such a project would not be practicable, because the foundress queen can do no more than make a small beginning, and thereafter the nest must be constantly closed to protect the brood from cold and damp. An equable temperature is necessary for the well-being of the grubs. The presence of the latter with a host of active nurses and workers provides adequate central heating, while excessive radiation from the nest is prevented by the construction of its envelope, which consists of from two to four layers separated by air-spaces. If the air in the nest gets too hot and humid a number of workers range themselves near the entrance and fan vigorously with their wings—just as hive-bees do in similar circumstances.

If an inhabitant of Lilliput were small enough to enter a wasps' kingdom he would realize at once that he had set foot in topsy-turvydom. Standing on the smooth surface of one comb, and looking vertically upward, he would see right into the cells of the comb next above. Some of these would be seen to contain eggs, others grubs in various stages of development, while still others would be closed to inspection by white, domed caps of spun silk. In these last are hidden wasp-pupae undergoing their final transformation.

Why the wasps should have chosen this head-downward method of cradling their young, rather than the horizontal one

favoured by the hive-bee, is hard to conjecture, especially as it involves an obvious disadvantage. We have seen that the queen glues the egg to the side of the cell. When the grub hatches it remains for a time with its tail-end in the egg-shell, moving freely on this pivot and craning its head to the opening of the cell to receive the food brought to it by the workers. But as its bulk increases it must change its position in order to avail itself to the full of the accommodation which its cradle affords. It has only two prehensile organs, namely its jaws and a kind of sucker foot at the opposite extremity. Thus, if it relaxes its hold at one end before making fast at the other it naturally falls headlong from the cell. Such accidents are far from rare ; and it seems astonishing that their frequent occurrence should not have taught the wasps that vertical cells opening downward are unsafe receptacles in which to rear their brood. On the contrary, they accept the catastrophes as matters of course, never attempting to replace the unfortunate infants, but carrying them away to the refuse heap at some distance from the nest.

The lucky grubs that succeed in fixing their sucker-feet firmly to the roof of their cells have soon nothing to fear, for in a few days they grow so corpulent that they fit tightly into the space provided. At regular intervals they are supplied with nourishment by their nurses, their diet consisting of the soft parts of insects chewed into a sort of pap, varied occasionally, perhaps, by a mouthful of nectar or fruit juice. In from ten to fifteen days after hatching the grub is full-fed and spins a silken cap over the mouth of its cell. This done, it changes in privacy to an ivory-white pupa, which in due course develops into a mature wasp. Under favourable conditions the whole metamorphosis from egg to perfect insect is accomplished in rather more than three weeks ; but the newcomer is pale and weak at first and passes a period of probation within the shelter of the nest ere she goes forth to fend for the community.

The subsequent life-story of the individual worker wasp is soon told. At first, when young and vigorous, she devotes most of her energy to foraging and to the maintenance and enlargement of the nest. But ere long—probably in less than three weeks—her powers of paper-making fail her. She may now be styled “an old wasp”, and finds fitting employment for her declining days

chiefly in feeding and cleaning the hungry grubs, which attract attention to themselves by scraping the wall of their cells with their jaws. Although she nourishes her charges mainly on insect fare, she herself displays a marked preference for syrups and sweets, visiting the ripe fruit in our orchards and any exposed sugary substances in our houses and shops. She also imbibes nectar from certain flowers, notably the little liver-coloured bloom of the figwort; while she may often be seen regaling herself at the tiny nectaries situated on the underside of laurel leaves close to the stalk. Moreover, a sort of *bonne-bouche* is provided by the grubs, which at regular intervals exude a tiny drop of clear, sweetish fluid from a gland on the labium or lower lip. This is always licked up by the nurse when food is brought to the cell's occupant. Besides feeding and tending the grubs, a certain number of workers are in constant attendance upon the queen, keeping her supplied with the rich and liberal diet needed to sustain her protracted duty of egg-laying.

Another task devolving upon the workers is the maintenance of sanitary conditions within the nest. This is to some extent simplified by the fact that shortly before casting its skin and changing to a pupa the grub ejects from its anal opening a sac containing the whole of the waste matter evacuated from the alimentary canal during its larval life. This dark-coloured but inodorous mass, together with the cast-off skin, are left in the cell, flattened against its roof, after the exit of its tenant; and by counting these relics the number of times that the cell has been occupied can be ascertained. From this it appears that no cell is used more than thrice. Before a cell is used again the workers tidy it up, removing the remnants of the cap and clearing away the silken lining which formed part of the cocoon. Then a fresh egg is laid in it by the queen. Adult wasps invariably discharge their excrements when away from home, and carry out dead grubs and refuse of all kinds to be dropped at a distance from the nest; but unlike ants, they do not co-operate in pairs or teams; so any offensive object—such as the corpse of a slug or a caterpillar—too large to be removed by one individual is left lying and roofed over with thick wrappings of paper.

Until the end of the summer the population of a wasps' nest consists of the foundress-queen and her huge family of workers:

but at the approach of autumn the latter start suddenly to build larger cells at the periphery of the lower combs, and any comb that may be added subsequently consists entirely of these more commodious compartments. In them a number of princesses (or potential queens) and males (or "drones") are reared. Exactly why princesses rather than workers develop in these special cells is a problem still awaiting solution. It may be due to a change in the constitution of the egg itself, or to the kind of food supplied to the grub, or to both these factors in combination. Somewhat later in the season some of the workers may start laying unfertilized eggs, which give rise only to males. Hence, the drones of a community—which on the average seem to be about twice as numerous as the princesses—may be either the sons of the foundress-queen, or her fatherless grandsons.

When the young princesses emerge from their cells they attain sexual maturity in a few days and then usually leave the nest. Pairing takes place in the open, either with males from the same family or those from neighbouring communities; and, after a period devoted chiefly to feeding, dry and sheltered hiding-places are sought where the winter may be passed in safety.

The advent and amours of these royal personages do not greatly interfere with the well-ordered activities of the community so long as calm, sunny weather prevails. The workers still bring home food and building materials, the grubs are fed and cleaned with due care, and if need be the fabric of the nest is repaired and strengthened. Yet the prescient observer is aware that the day of the wasps is nearly ended—that their kingdom is about to fall. The first frost will strike to the heart of this once prosperous community. Starvation ravages it, for its builders store no sustenance within its paper walls, and with the falling temperature go no more abroad in search of provisions. Thus they die—die by tens, by hundreds, by thousands, the enfeebled workers often dragging the half-grown grubs from their cells and dropping them outside the nest that they may share the common fate. For a short while the drones—recognizable by their extra long antennae and narrower abdomens—may be seen in numbers frequenting the flower-heads of late-blooming umbelliferous plants and of the ivy; but they, too, soon perish, and only the procreant princesses survive until the spring.

One might suppose that insects as alert and irascible as wasps would successfully ward off parasites and intruders. Yet in fact they are frequently victimized by the strange-looking paradoxical beetle, the common and German species being the worst sufferers. The female, with instinctive cunning, lays her eggs on palings and other woodwork. When the tiny larvae hatch, they lie in wait until a wasp comes to gather fibre for paper-making, spring upon her, and are thus carried to the nest. Each little rascal then makes its way into a cell, and fixing upon the grub which is the rightful occupant begins deliberately to imbibe its life-blood. So carefully, however, does the parasite regulate its appetite that the wasp-grub still preserves sufficient strength to spin its cocoon. But this is the signal for the intruder to consummate its dark deed. The wasp-grub is then literally sucked dry, and the now fully nourished beetle-larva completes its metamorphosis in the stolen cell, reposing upon the empty skin of the victim.

Although the wasp-nurses constantly investigate the cells when they come to feed their charges, they seem never to discover the parasites. Yet when the perfect beetles emerge they have to run the gauntlet of the whole community in order to escape from the nest, for the wasps now recognize them as intruders and display a fitting hostility. Probably only a few of them make good their escape, for this curious beetle is regarded by collectors as a rarity.

An even rarer cock-tail beetle, similar in build to the all-black devil's-coach-horse but densely clothed with long, yellowish hairs so that it looks somewhat like a humble-bee, has more than once been seen to enter holes in hollow trees tenanted by colonies of hornets, and is known to lay its eggs on the combs of these formidable insects. According to H. St. J. K. Donisthorpe, the larvae are not parasites, as was formerly supposed, but act as scavengers by feeding on dead hornet-grubs and other refuse, thus helping to keep the nest clean. The hornets neither molest them nor the adult beetles which, after completing their metamorphosis, make their way to the open, there to prey upon the larvae of certain beetles, especially, it is said, those of the dumble-dor family. Other tolerated aliens that pay their footing in the same way are the grubs of a fly whose coloration imitates very closely that of the hornets among which it forgothers.

The grubs of the pellucid drone-fly, a shining black species with a pale, translucent band at the base of the abdomen and a dark, median blotch on each wing—reside on similar terms in the subterranean habitations of the common and German wasps where—according to Fabre—their parent is “welcomed peaceably when it penetrates into the burrow to lay its eggs, and thus in the very heart of the dwelling, where no stranger may wander with impunity, its larva is tolerated and even respected”. Another two-winged fly—not unlike the destructive onion-fly in appearance—also walks unchallenged down the tunnel leading to the nest to deposit its eggs on the outer covering. When the larvae hatch they drop immediately to the ground below, where a considerable amount of organic matter accumulates, and on this they feed.

Besides these beetles and flies, many other creatures, insects and small invertebrates of various kinds, occur with more or less regularity in wasps’ nests, some entering as barefaced thieves, others with parasitic intent, while still others are attracted by the promise of warmth and shelter. Most notable are the greyish-white caterpillars of the green-shaded honey-moth that are sometimes present in considerable numbers, weaving their silken galleries in the fibrous substance of the nest, which seems to serve as their chief food.

In the open, wasps in pursuit of their lawful business are exposed to the attacks of robber-flies, those ruthless savages of the insect world which hawk their prey on the wing. In Britain the largest and most spectacular example of the breed is the hornet-like robber-fly whose coloration closely resembles that of its namesake. This has been advanced as a case of what is called “aggressive mimicry”—i.e. the superficial similarity of a predatory creature to its victims, whereby capture is facilitated.

The only mammalian enemy of social wasps in Britain is the badger. In some districts where these rather bear-like beasts are still numerous they seek out and dig up many nests to eat the grubs, their thick, coarse fur affording them complete protection from stings.

The habits and economy of our two tree-nesting wasps differ little from those of the subterranean species described above, but their colonies are less enduring and never so populous.

In architectural practice, however, there are notable distinctions, especially in the outer covering of the nest, which consists of long strap-like sheets of grey paper laid on horizontally instead of scaly patches added more or less at random. The commoner species is the wood-wasp which, although its shapely nest usually hangs from a low branch of some shrub or tree, occasionally builds under cover—e.g. in a hollow tree-trunk or a hole in a hedge-bank. The nest of the Norwegian wasp, which invariably hangs from a branch, is somewhat pear-shaped in outline and more compactly built, the overlapping sheets of the envelope pressing closely on one another at their edges. This species has been called “the queen of paper-makers”, while the pertinacity of its workers is phenomenal. The survivors of a community robbed of its nest have been known immediately to set about building a new one, undeterred by the fact that their queen had also been destroyed.

Excepting South America and Australia, Vespid wasps similar to those found in Britain occur throughout the world in countries with temperate climates. The hornet, however, belongs to a group represented chiefly in the warmer regions of Asia and the East Indies, some members of which are entirely nocturnal and are distinguished by their pale, ghost-like coloration and abnormally large eyes. But generally speaking the social wasps of the tropics are of a different type, being for the most part slenderly built insects comprised in a sub-family known as *Polybiinae*, the majority of which belong to Central and South America.

The nests of these Polybiine wasps vary greatly in size and appearance. Usually they hang from a branch, but the smaller ones, which are often exquisitely dainty structures, may be attached to the surface of a broad leaf, or to the trunk of a tree. Some, like those of our chaffinch and bottle-tit, are camouflaged with scraps of lichen fixed to the outside of the envelope, so that they are rendered all but invisible. The more bulky represent the labour of several successive seasons, during which they have been added to and repaired; for with few exceptions the colonies of these wasps are perennial, sending out swarms when overpopulation is imminent. Some exceptionally large nests are believed to have persisted for a quarter of a century or more. One, collected in the Amazon Basin, measured more than two

feet in length and consisted of twenty-two tiers of combs. At a conservative estimate its inhabitants must have numbered tens of thousands of individuals. A newly established community may break up quite soon, or it may remain intact for several years before swarming begins. The leader of a swarm seems always to be a young, fertilized female.

Brazilian wasps of the genus *Chartergus*, known locally as "matabunters", build nests whose outer covering is so thick and tough that a sharp knife is needed to cut through it, while the surface is so smooth and white that it can be written on with a fine pen. These nests, which are suspended by a short, stout stalk from a branch, are roughly bell-shaped, the combs being completely enclosed, save for a small entrance-hole in the centre of the convex lower part. A corresponding opening is left in the centre of each of the combs, which are attached by their edges to the inner wall of the envelope—a labour-saving method of construction obviating the need for supporting pillasters between them. It also economizes material, since when more accommodation is required none of the existing structure need be cut away—as is customary with our native Vespid wasps. Instead, an additional comb of cells can be built outside the lower extremity of the nest and subsequently walled in by an extension of the envelope. This is the style of building generally employed by Polybiine wasps. In some instances their nests are studded externally with numerous rough knobs or angular projections, which may serve to discourage attack by four-footed creatures tempted to breach the bulwark in order to investigate the interior.

A small group of South American social wasps build their nests entirely of sun-baked clay, with a lengthy perpendicular slit in one side for entry and egress. Two examples of these remarkable strongholds from Bakia are preserved in the British Museum (Natural History). The outer covering, or shell, of one that has been broken open measures from a quarter to half an inch in thickness, while the cells within are as perfectly formed as if they had been moulded on a potter's wheel.

Most of these wasps prey on insects, and sometimes when their captures are in excess of the brood's immediate need lay up the surplus in reserve for use when food is scarce. But the

interesting honey-wasps collect nectar from flowers and store it in their cells. This was first noticed towards the end of the eighteenth century by De Azara, a Spaniard, who had lived as an explorer for many years in Paraguay; but at the time when his memoirs were published many entomologists were sceptical, believing that he had mistaken bees for wasps, while others treated his statement as a mere traveller's tale. Some forty years later, however, some nests were sent to the British Museum (Natural History), and when these were examined by the late Dr. Adam White dry honey was found in the combs. In Mexico the nests of the local honey-wasps are left unmolested until they attain a certain size, when the inmates are smoked out and the sweet content drained off.

In all tropical countries ants are the principal assailants of social wasps. Dr. O. W. Rickards—who, with his wife, made a special study of these insects in British Guiana—tells us that they safeguard themselves by various means, notably by the establishment of friendly relations with the enemy. "A few species have achieved this, in what way we do not yet understand, but they build their nests almost exclusively on trees harbouring enormous ants' nests. These ants do not molest them, and the wasp colonies are in many cases long-lived. Several kinds of birds have learnt to build their nests on the same trees and seem to have the same immunity." First to colonize a tree are the ants, the wasps taking up residence later. But this state of tolerant co-existence is impossible where the driver ants are concerned, since these formidable foes live as nomadic hunters without fixed abodes.

In these circumstances a small, easily abandoned nest with several resident queens seems most likely to ensure the survival of the community—though not, of course, freedom from molestation. "A small nest does not represent a large stock of capital and when the ants make an attack the wasps can desert the nest without irreparable loss. The queens, because there are several of them and none of them has been laying at a very high rate for long, have lost none of their mobility. They are not nest-bound like the old queen of the common wasp. With the aid of the swarm of workers a new nest can be constructed in twenty-four hours."

Chapter Five

THE HOUSEKEEPING OF THE HUMBLE-BEE

UPWARDS of 1,500 different kinds of bees have been described from various parts of the world, not far short of 250 occurring in Britain. Generally speaking, these all agree in possessing certain peculiarities which distinguish them from other "aculeate" members of their Order—i.e. from those whose females are equipped with stings. Perhaps the most significant feature is the structure of their mouth-parts other than the mandibles. These, when compared with those of wasps and ants, are greatly elongated, sometimes to a surprising length, so that they form an apparatus—often termed collectively the "tongue"—adapted for extracting nectar from the tubular corollas of flowers. Scarcely less important, however, is their equipment for gathering and transporting pollen—the plumose or feathery hairs, and the so-called "baskets" on the enlarged basal joints of the hind tarsi which have already been described. Like the sting, all these are essentially feminine characteristics, the sterner sex visiting flowers solely for their own delectation, not in discharge of domestic obligations.

A few exceptions should be noted. The leaf-cutter bees and some others carry home their pollen on the underside of the abdomen instead of piled up on the "baskets" of the hind-legs. Again, the little coal-black, white-faced bees of the genus *Prosopis* have short tongues, like those of wasps, and are so scantily clothed with hairs that they cannot gather pollen in the ordinary way, and in default gulp it into their crops along with nectar, later regurgitating the mixture as provision for their young. Indeed, the members of this particular genus differ so little from the less-specialized wasps in structure and habits that but for their choice of food one might question whether they were bees at all. But bees, as such, are confirmed vegetarians. Pollen and nectar constitute their own food and the staple with which they feed their offspring. On the other hand, while many kinds of wasps frequent certain flowers and imbibe their sweet secretions,

they invariably nourish their brood with small invertebrates, chiefly insects and spiders.

These facts suggest that bees, as a class, may have descended from ancestors whose manners and customs were similar to those of existing digger-wasps, and that their subsequent differentiation depended mainly upon the discovery that the food which they themselves consumed could be fed satisfactorily to their progeny. Moreover, vegetable products, less liable as they are than animal matter to early decomposition, can be stored in quantity for winter use ; and this goes far to explain the evolution of enduring communities, such as those of the hive-bee.

In an earlier chapter several instances were cited in which so-called "solitary" wasps and bees make their nest-burrows close together in the same situation, working side by side harmoniously, yet without actual co-operation. But it was not, apparently, through gregariousness that the true social community came into being. For this the indispensable condition seems to be an overlapping of generations, so that the mother may associate with, and be assisted by, the adults of her family. Some of the diminutive burrowing bees of the genus *Halictus* come very near to a realization of this requirement. The adult males and females make their appearance in the autumn, instead of remaining in the cells as pupae, as is the case with most other solitary bees. After pairing, the males die off, but the females hibernate and in the following spring start nest-building, either alone or working in small gangs. The latter combine to excavate a common burrow which gives access to the groups of cells made and stored by individual members of the colony. The burrow may also be widened near its entrance to form a vestibule enabling the bees to pass one another easily as they come and go, while a sentinel is often posted to keep out would-be intruders. Thus, the conditions obtaining have been aptly likened to those of several families occupying a block of flats but all using the same front door, kept by a porter.

Detailed information is still lacking ; but in the case of these co-operative colonies the early brood seems to consist solely of females which, although they differ little externally from their mothers, have imperfectly developed ovaries, and may be regarded as incipient workers. They play an important part in excavating

and provisioning the cells in which their parents—those females that have hibernated—continue to lay eggs. So far as is known, the autumn-bred, sexually mature females—destined to survive the succeeding winter—all hatch from eggs laid by these veteran “queens”, as they may be called, whereas males are produced either from their unfertilized eggs, or from eggs laid by the workers. Similarly organized societies of bees belonging to genera other than *Halictus* occur in South Africa and elsewhere, but these have not yet been studied as closely as those of the European species.

The humble-bees—a well-marked social group represented in Britain by about a score of species—are believed to have originated in South America, where solitary bees similar in structure are still found. With the exception of this sub-continent these insects are scarce or absent in the southern hemisphere, but occur numerously all over the northern hemisphere, especially in temperate regions. In their communal mode of life they stand midway between the bees with rudimentary social behaviour described in the preceding paragraphs and those of the genus *Apis*, to which the domesticated hive-bees belong. Some nest in holes in the ground, others—the so-called “carder-bees”—under an accumulation of dry moss and vegetable refuse in such situations as the shelter afforded by a tussock of grass, the caves of a cottage or outhouse, or occasionally in a disused bird’s nest. On more than one occasion the present writer has known a pair of blue-tits to be ousted by a humble-bee from a nest-box in which the hen-bird had already started to lay.

The subterranean humble-bee—such as the big black-and-yellow banded species with a buff-coloured tail—seem usually to take advantage of the deserted burrow of a field-mouse or some other ready-made excavation, which may subsequently be enlarged as the population of the colony increases. The approach to the nest proper is through a tunnel, which may be of some considerable length. This leads to a chamber, often lined with moss, dead leaves or fragments of grass, though this packing may be absent, in which case the insects protect themselves from damp and draughts by stopping crevices with a resinous material apparently similar to the propolis used by hive-bees for the same purpose.

When divested of its covering the central part of the nest is seen to consist chiefly of buff-coloured objects not unlike small snake's eggs in appearance. These are the cocoons spun by the bee-grubs prior to their pupation. At first glance they appear to be huddled together anyhow, but careful examination shows that they are set side by side, and—if the nest is an old one—piled one upon another in two, or even three, tiers. Most of those on the ground-level are minus their domed tops, having been vacated by their makers and occupants. Some of these are empty, but others contain a viscid liquid which, on being tasted, proves to be honey. The cocoons of the upper tier or tiers are completely closed : in each a bee-pupa reposes, awaiting its final transformation.

Winding passages traverse the mass of cocoons, enabling the adult bees of the colony to pass to and fro about their business. But at first sight there are no signs of eggs or young—the rising generation whose presence is naturally anticipated. On closer inspection, however, certain hummocks of a chocolate-brown substance are noticeable resting on some of the uppermost cocoons. These are the roughly constructed receptacles in which the brood is reared. The smaller contain five or more elongate, slightly curved, shining white eggs : the larger as many grubs in various stages of growth. For although the eggs in each cradle were all deposited approximately at the same time, the larvae do not hatch simultaneously.

Compared with that of the social wasps and the hive-bee the architectural skill of the humble-bee is of a low order, following no definite plan or system. The cells—if so they may be called—lack symmetry of form, vary considerably in size, and are used only once as nurseries, new ones when needed being built upon those which have been discarded, or wherever room can be found. As a result, an old nest presents a very irregular and untidy appearance.

The queen-mother or queen-foundress of a colony, when she issues from her winter hiding-place in the spring, seeks at once for a suitable nesting-site. If she is a member of an underground species she investigates holes in hedge-banks facing south, visiting one after another until her instinctive requirements are satisfied. Within the chosen retreat she proceeds to fashion a cup-shaped cell, the inner wall of which is coated liberally with honey-

saturated pollen, and—after laying several eggs—roofs it over completely. Next comes the making of one or two tubs, to be filled subsequently with honey—reservoirs, these, to be drawn upon for feeding the grubs, more especially on rainy days when visits to the flowers are impracticable.

When the grubs hatch they soon lick up the food which has been provided ; and thereafter the watchful mother supplies them with frequent rations discharged from her mouth through a small hole made for the purpose in the cell's roof. As they increase in size, the grubs push the soft sides of their nursery outwards into bulging pockets, more plastic material being added from time to time, as required, by the queen. Moreover, the indefatigable creature, still labouring alone, proceeds to make more cells and to lay more eggs, thus increasing the size of her family.

When fully fed, each grub spins for itself an oval cocoon of extremely fine silk in which its metamorphosis is completed. Given plenty of nourishment, the development of a humble-bee, from egg to perfect insect, takes from three to four weeks ; so that about a month from the assumption of her responsibilities the queen-mother is surrounded by a little company of four or five daughters, ready to bear their part in the daily round of foraging for and feeding the brood ; and as week after week passes these helpers increase in numbers, enhancing the prosperity of the colony. The originating queen now ceases from all activity except egg-laying, and seldom if ever leaves the nest. In some instances she actually loses the power of flight. Her daughters—the workers, as they must now be styled—build cells, see to the sanitation of the nest, and go abroad, to return laden with pollen and nectar.

According to F. W. L. Sladen the subterranean species have a way of feeding their brood different from that followed by the surface-nesters or carders. The latter “form little pockets or pouches of wax at the side of a wax-covered mass of growing larvae in which the workers drop the pellets of pollen direct from their hind tibiae” ; whereas the former “store the newly gathered pollen in waxen cells, or in old cocoons, specially set apart to receive it, from which it is taken and given to the larvae mixed with honey through the mouths of the nurse-bees as required”—a method, this, similar to that employed by hive-bees.

The first workers to make their appearance are small, sterile females, but those which are produced later in the season, if males or drones are also forthcoming, frequently become fertile, thus adding to the numerical strength of the community. Yet even in the most favourable circumstances the population of humble-bees' nests is relatively insignificant by contrast with that of a bees'-hive, or the pasteboard fastness fashioned by social wasps. Of the larger species with subterranean proclivities the total number of individuals rarely exceeds four hundred, while in the case of a carder-bee it may be less than a couple of score, although an exact estimate is always difficult to arrive at, because when the count is attempted some of the residents are likely to be abroad. For if caught by heavy rain, or if far afield when twilight falls, humble-bees often pass the night away from home, sleeping in the corolla of a flower, or some other convenient place of shelter.

Although female humble-bees are equipped with serviceable stings they rarely use them unless roughly handled or in defence of their nest. The subterranean species are noticeably more pugnacious than the surface-dwellers. The easy-going temperament of these insects as a whole is reflected in the fact that their honey-tubs are never sealed up, but left free and open for any that may be hungry to take their fill. In favourable weather the quantity of nectar and pollen gathered and stored may be considerable.

The dark-coloured wax used by humble-bees is produced as thin plates from between the overlapping abdominal segments and raked off by combs on the hind-legs, after which it is macerated and moulded into the required shape by the jaws. But it differs in chemical composition from that of the hive-bee, is less ductile, and if burnt leaves a carbonaceous residuum which readily attracts moisture.

Because of their relatively large size, velvety clothing and gay colouring humble-bees are peculiarly attractive. They are also notable for their industry, leaving the nest as early as three or four o'clock on fine mornings, and on summer evenings, if the temperature is high, not returning until after sundown. By contrast, most solitary bees do not commence work before 9 or 10 a.m., and generally cease about 4 or 5 p.m. Some two and a

half centuries ago the Dutch naturalist Goedart stated that some species of humble-bees appoint what he termed a "trumpeter" to rouse the rest of the community at daybreak by fanning with its wings and making a loud humming noise. For a long time this was treated as a pleasing fantasy. But in the latter part of the nineteenth century his statement was confirmed by the Austrian entomologist Hoffer, who observed the trumpeter performing in a nest kept in his laboratory, and noted that if the authorized individual was removed its place was filled by a substitute the next morning. Doubt still exists, however, as to whether the fanning of the wings really serves as an alarm or merely to ensure ventilation, for it sometimes occurs also in the evening.

The grades or castes among humble-bees are less clearly defined than those of the hive-bees, and in this respect these insects more nearly resemble the social wasps. The females differ from one another chiefly in size and in the degree of their fertility. Those which come from the first-made cells are chiefly, if not exclusively, of the sterile or worker type. But when a colony has become established numerous small but perfectly developed females make their appearance, and these frequently lay eggs which, in default of pairing, apparently give rise only to males. If, however, they find partners—as sometimes happens quite early in the season—some of their eggs may produce females. Our knowledge of the causes which operate for or against their fertility is still far from complete; but there is no doubt that in the event of a colony being deprived of its foundress or reigning queen, it can still maintain itself in being, thanks to the female-producing eggs laid by these lesser royalties or princesses.

During the late summer or early autumn a number of specially large females make their appearance and mate with males or drones, either of their own or a neighbouring community. These are the foundress-queens that hide away until the succeeding spring, when they become the mothers of fresh communities. This is the normal procedure in temperate regions; but some tropical humble-bees are believed to found new colonies by swarming.

At the close of the season, as long as the weather remains mild and calm, male humble-bees may often be seen flying slowly along hedge-banks or among low-growing vegetation evidently

seeking mates, which they apparently track down by scent. Of the actual courtship and nuptials W. E. Shuckard gives the following graphic description, based presumably upon his own observations. "In their amours, the autumnal females evince considerable coquetry to attract their partners: they place themselves upon some branch in the most fervid sunshine, and here they practise their cajoleries in the vibrations of their wings, and allure them by their attractive postures. The males are simultaneously abroad, and soon perceive them. The seduction is complete, and they pounce down upon them with impetuosity, but their brief indulgence terminates in death, for with his abating vigour the female repulses him, and he falls to the ground never to take wing again."

Bees, as is well known, play an indispensable part in the pollination of many flowers, thus ensuring their fruitfulness. Hive-bees, for example, are invaluable to the farmer and gardener as fertilizing agents of white or Dutch clover and fruit blossom; but they are of little service where broad beans and red clover are concerned, since in these instances long-tongued humble-bees are needed effectually to operate the floral mechanism. When red clover was first introduced into New Zealand, where there are no native humble-bees, the crops yielded so little seed that fresh supplies had to be imported annually. This state of things continued until about 1880, when living humble-bees were sent out from England, with the result that in a few years' time plenty of red clover seed set and ripened. Unfortunately, some of these insects have the habit of biting a hole through the corolla of a flower whose nectar they cannot easily reach in the orthodox fashion, thus gaining access to the coveted dainty without touching the essential organs. In this respect the large, buff-tailed humble-bee is especially culpable, and F. W. L. Sladen states that its depredations in New Zealand have been so serious that "the seed-growers there would now be glad to have this species supplanted by another".

Many familiar flowers owe their fertility chiefly, if not exclusively, to the visits of humble-bees. One example is the monkshood, which in northern Europe grows wild only in localities where these insects occur; while those with the longest tongues are no less indispensable to the larkspur and the columbine. The snapdragon, again, is nearly always pollinated by the big

and burly species, although some of the smaller ones manage occasionally to nose their way between its tightly closed lips. Bulk, too, is obviously needed for forcing down the "keel" petals of a large papilionaceous flower, such as a sweet-pea; and the foxglove, for a different reason, requires the help of the more massive humble-bees, which alone, by completely filling its bell-like corolla, get dusted with pollen. Still another flower that caters specially for humble-bees is the yellow iris or flag—a cunningly contrived trinity offering three separate lines of approach to its store of sweetness. To this the insect gains access by thrusting its head and shoulders into an opening roofed over by a pair of essential organs, and in so doing its hairy back brushes first against the stigma, then the anthers of the stamen. Assuming that it has flown from a nearby bloom it will cross-pollinate the one now engaging its attention, and from this, in turn, pollen is likely to be carried to the next one on its visiting list.

Several mammals are inimical to the well-being of humble-bees, including, it is said, badgers and even foxes, which when other food is scarce are alleged to dig up and eat the grubs and pupae. But, as Charles Darwin pointed out in an oft-quoted passage, their worst enemies are almost certainly field-mice, which destroy many nests and their contents. Statistics show that these insects are more plentiful in the neighbourhood of villages and small towns, where cats are kept, than in the remoter rural areas where these feline animals are few or absent. With this fact in view, we may question whether the wholesale destruction of such creatures as weasels, owls and the smaller hawks, which feed largely on these little rodents, may not be impolitic from the seedsman's standpoint—so intricately interwoven is the web of life.

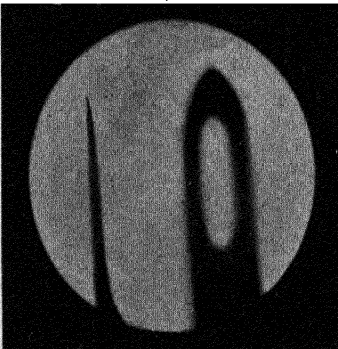
Among the minor birds of prey, shrikes or butcher-birds capture many insects, and are especially attracted by humble-bees because of their relatively large size, swooping upon them in mid-air and carrying them to their coign of vantage, where the victim is held down with one foot and torn in pieces. When the catches are not needed for immediate consumption they are impaled on the stout spines of a sloe or a hawthorn bush, or even on the barbs of wire fencing—the spot chosen by the bird for this purpose being known as its "larder".

Under lime trees in flower the mutilated corpses of humble-

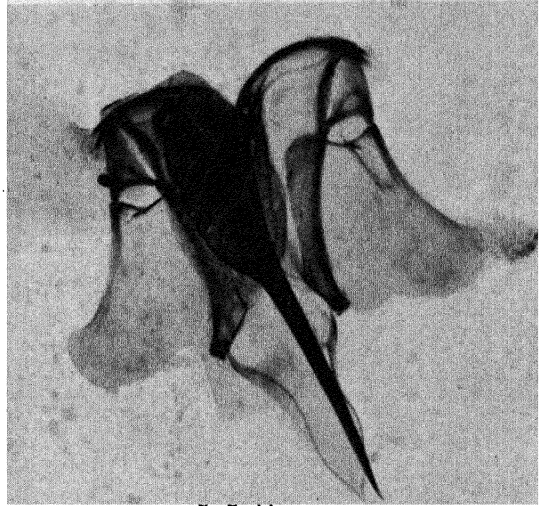
Plate I
MEN AND INSECTS
(Chapter I)



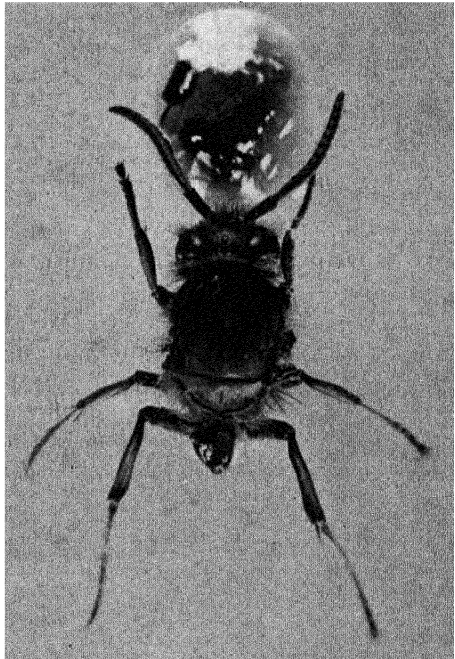
Stinging apparatus and poison sac of Wasp (from a model)



The sting of a Wasp contrasted with the eye of a medium size sewing needle



a Queen Hive-bee



Wasp, with nipped-off abdomen, feasting on a blob of raspberry jam. Note that a drop of jam is forming between the hind legs, at the truncated end of the alimentary canal

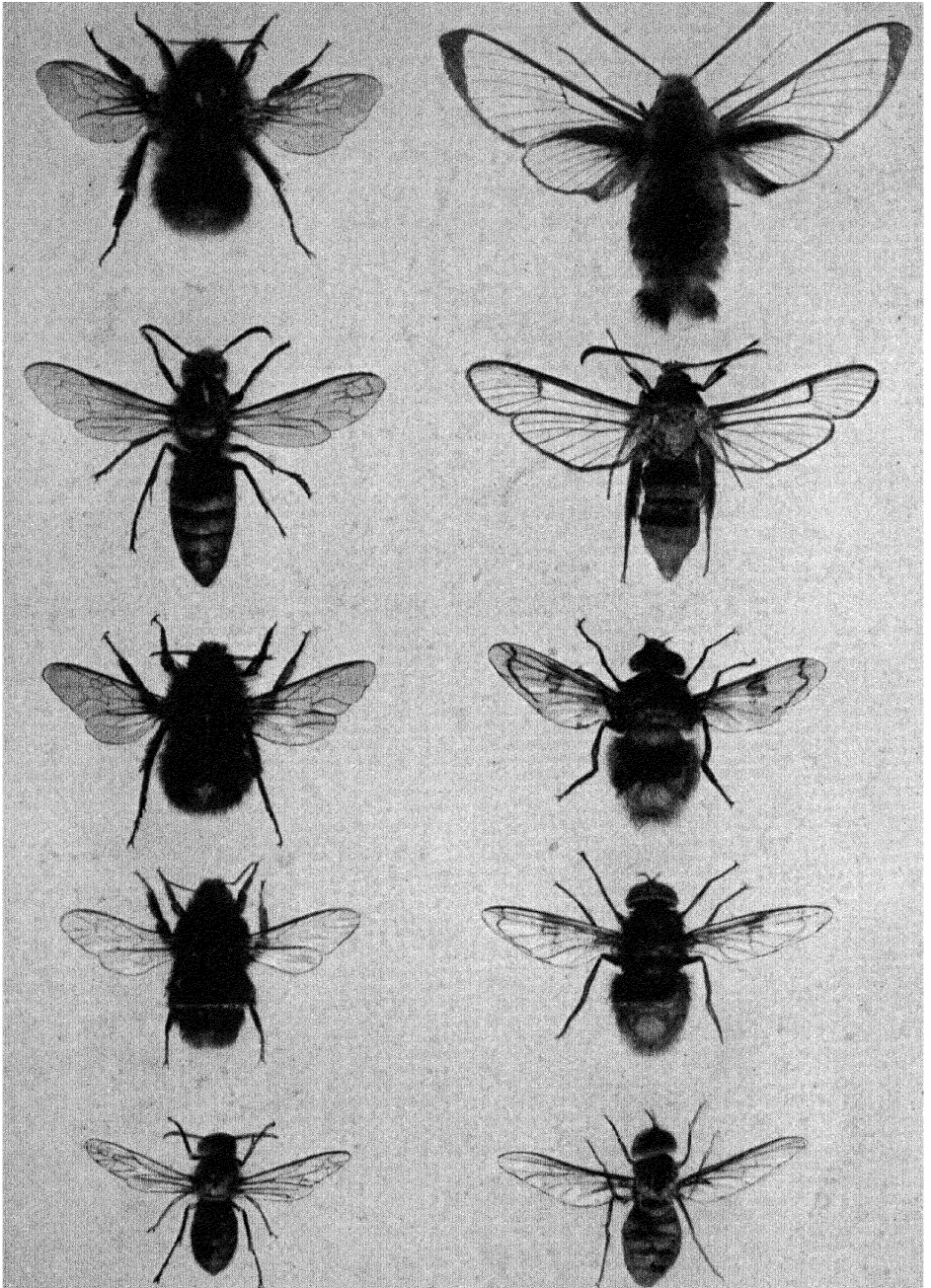


Plate 11

MEN AND INSECTS (Chapter 1)

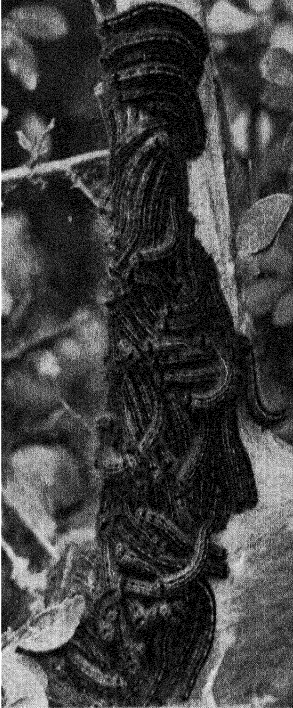
Mimicry of Stinging Insects by Moths and Flies

Left—Models

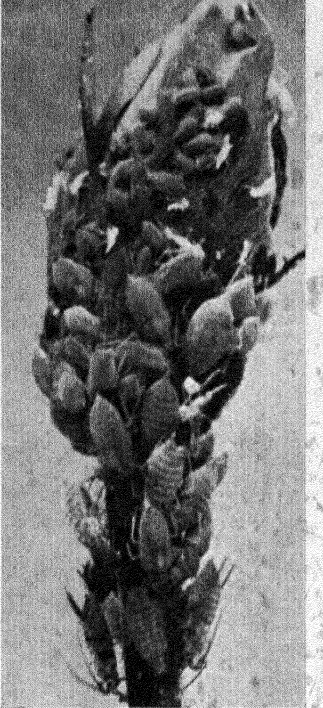
- Carder Bee—female
- German Wasp—female
- Carder Bee—worker
- Red-tailed Humble-bee
- German Wasp—worker

Right—Mimics

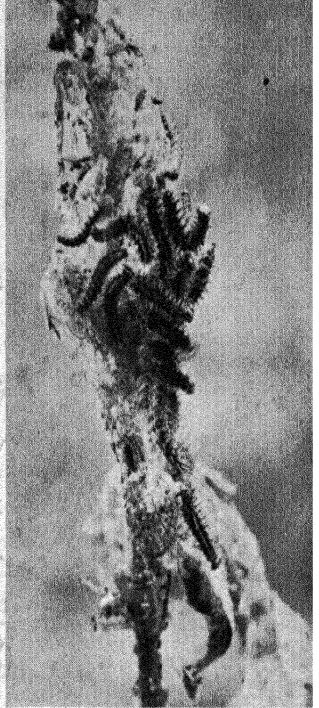
- Bee-hawk Moth
- Hornet Clearwing Moth
- Bee Fly—yellow form
- Bee Fly—red-tailed form
- Hover Fly



A family of Lackey Moth caterpillars sunning themselves on the outside of their tent



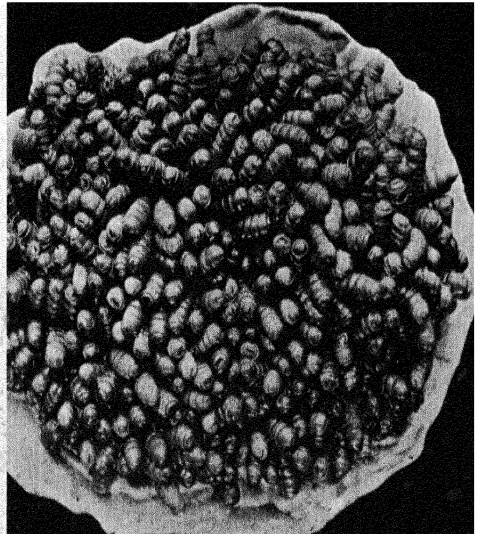
Colony of Aphides on a rosebud



Newly hatched family of Peacock Butterfly's caterpillars outside their tent sunning themselves



Hundreds of Spangle Galls on the underside of oak leaves



Gregarious larvae of the Horse Bot-fly attached to the lining of a horse's stomach—(see text)



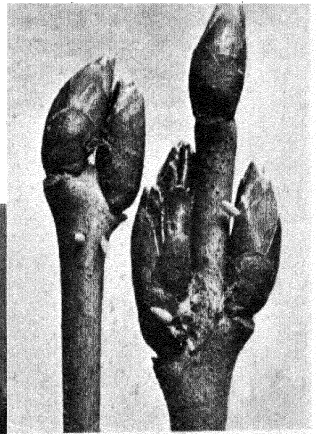
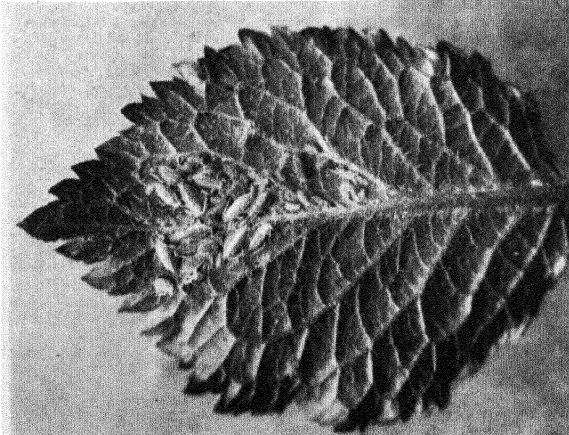
Anti-locust Research Centre

Close-up of a swarm of the Desert Locust

Plate IV

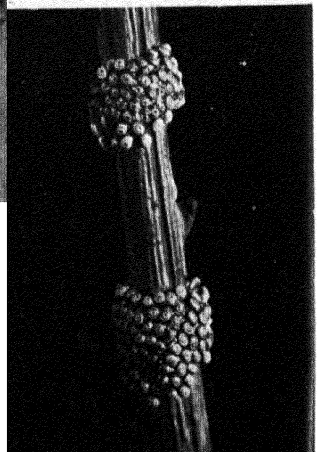
GREGARIOUS INSECTS (Chapter 2)

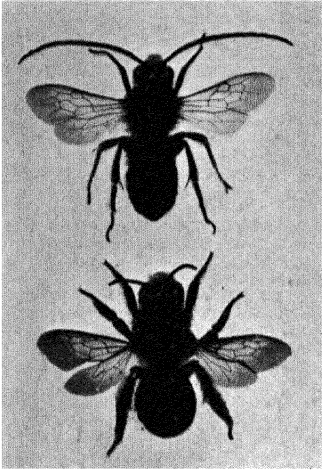
Colony of Aphides or green-fly (*below*) on the underside of a plum leaf



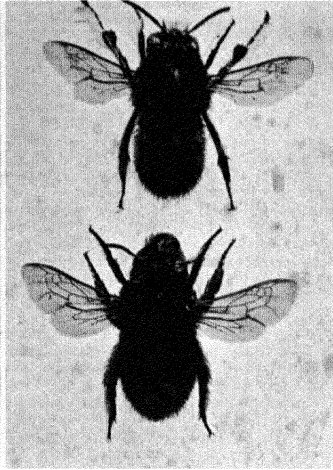
(*Right, top*) Four eggs of the Sulphur or Brimstone Butterfly, laid on or near Buckthorn leaf-buds—the species' food

(*Right, below*) Egg 'bracelets' of the Lackey Moth, laid round a twig (magnified). Eggs laid in Autumn. Caterpillars hatch out in the Spring

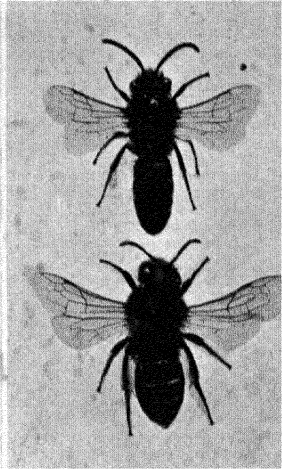




Long-horned Bee
(*Eucera longicornis*)
Male above, female
below

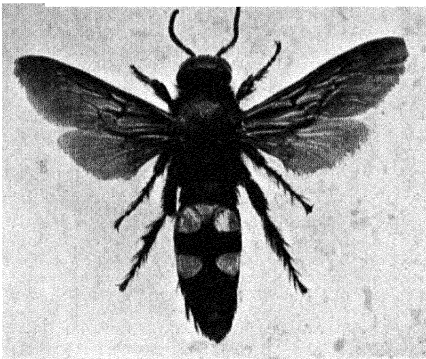


Hairy-footed Bee
(*Anthophora pilipes*)
Male above, female
below

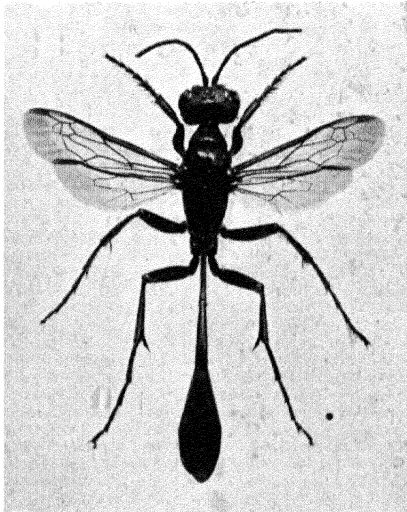


Colletes succincta
Male and female

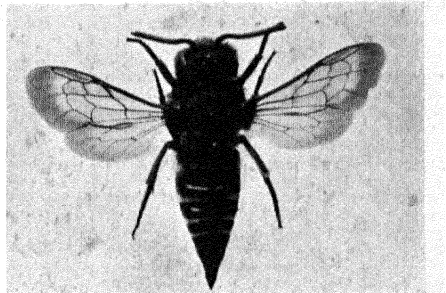
Plate V
INSECTS AS PARENTS
(Chapter 3)



(Left)
A European
Beetle Killer
Wasp
(*Scolitus sp.*)



(Left)
Heath Sand
Wasp
(*Ammophila
campestris*)

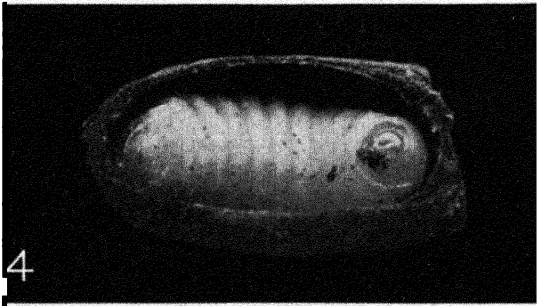
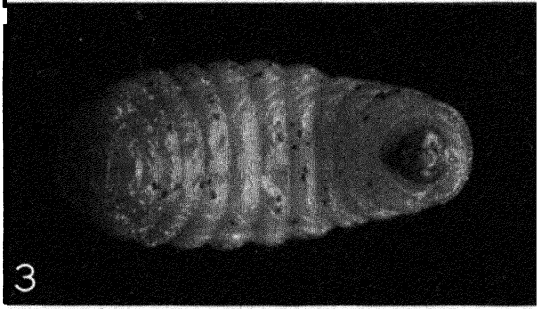
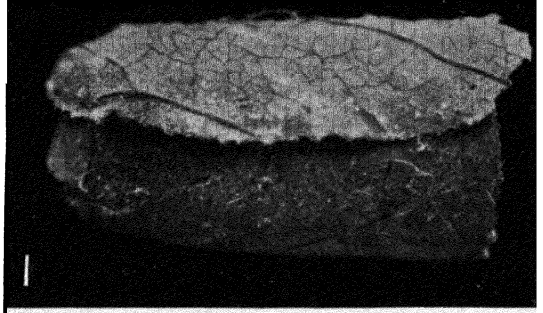


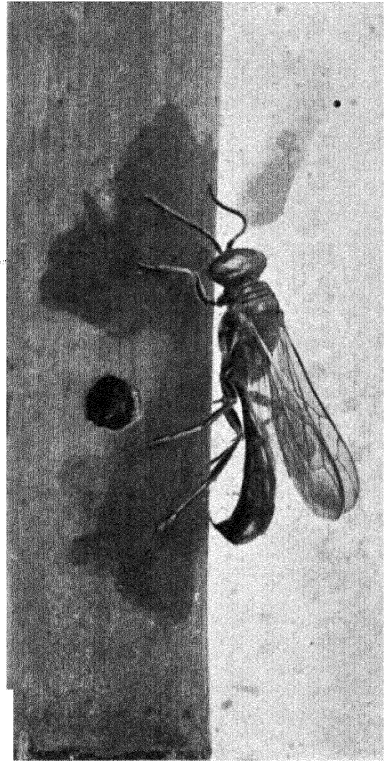
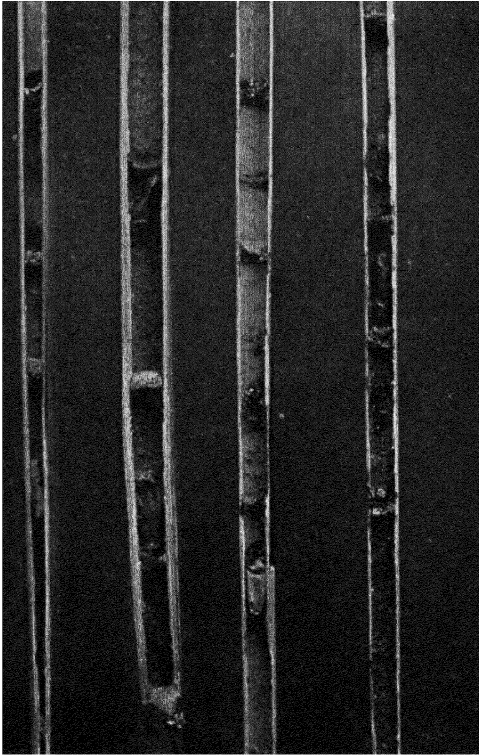
Cuckoo-parasite
Bee (*Melecta
armata*)

Plate VI
INSECTS AS PARENTS
(Chapter 3)

Stages in the life cycle of
a Leaf-cutter Bee

1. The cell
2. Cell cut open to show half-grown larva feeding on a mixture of pollen and honey
3. Full grown larva
4. Full grown larva in cocoon (cut open)
5. Pupa in cocoon (cut open)
6. Pupa, showing below its cast larva skin



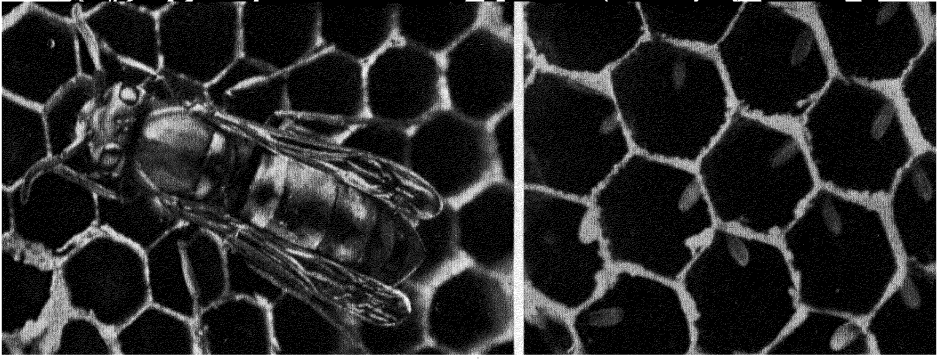


(Above, right) Black Borer Wasp (*Trypoxylon figulus*) on reed in the hollow of which it is forming its cells. Note the entrance hole bored by the Wasp.
(Above, left) Four reeds in section that have been bored by this Wasp

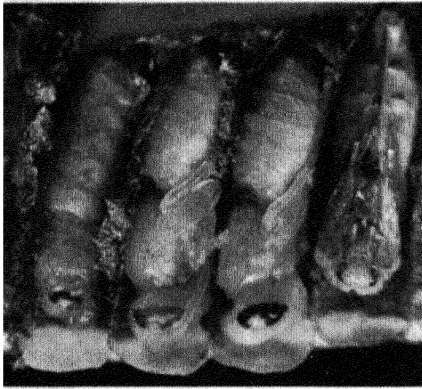
Plate VII
INSECTS AS PARENTS (Chapter 3)

Sand-wasp (*Ammophila sabulosa*) dragging a caterpillar to her burrow



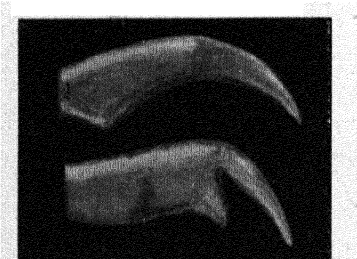


(*Top, left*) Queen wasp on comb of cells—egg-laying
 (*Top, right*) Eggs of wasp laid halfway down the cells

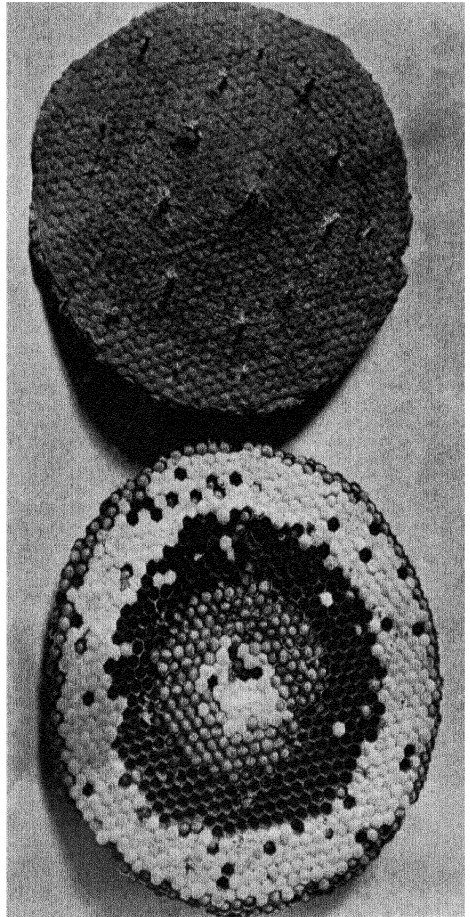


(*Left to right*) (1) Wasp's larvae changing to pupae; and (*extreme right*) a pupa of the parasite beetle (see text)

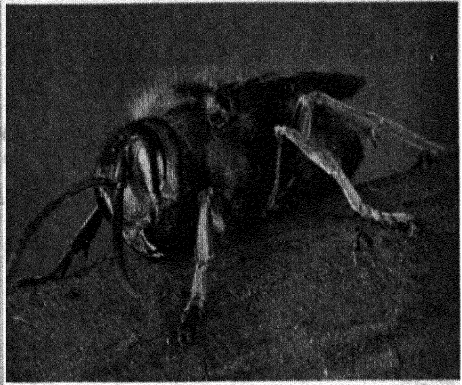
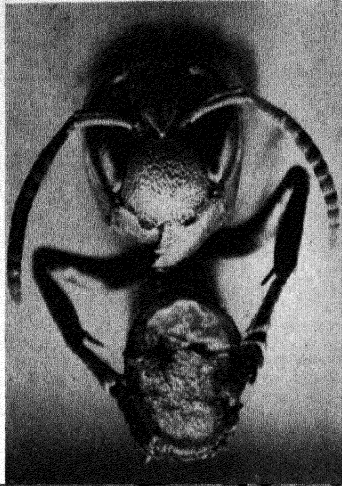
N.B. Wasps' larvae are reared head downward in their cells



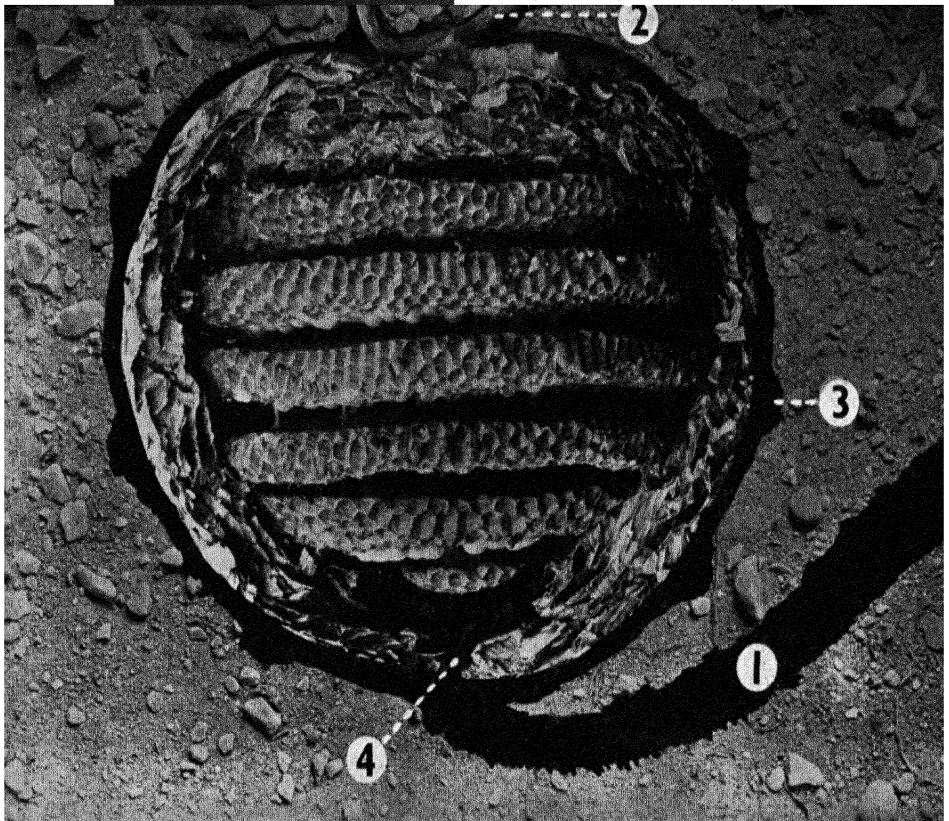
Claws of true wasps. (*Top*) Socials; (*below*) Solitary, both highly magnified (see text)



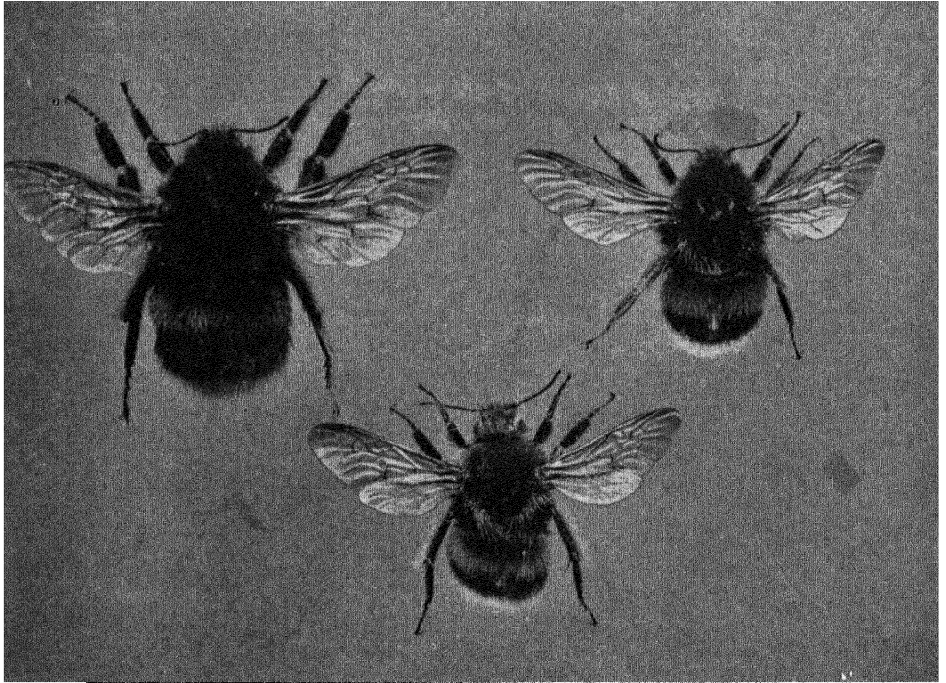
Two tiers of a wasps' nest. (*Top*) Upper surface. Note the attachments to the tier above. (*Below*) Under surface, many of the cells capped with silk



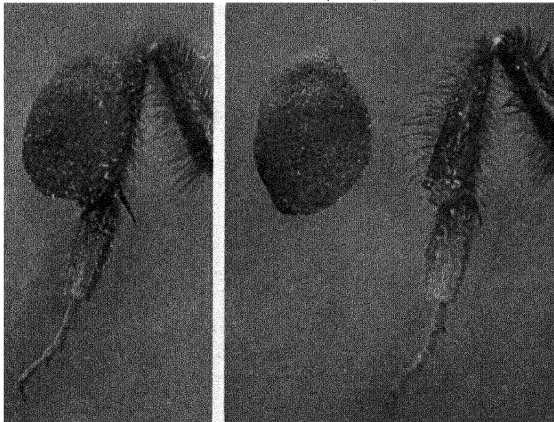
(Above) Queen Hornet. (Left) Face of a Hornet which is at the end of a twig, looking into the camera's lens



A subterranean wasps' nest shown in section, part of the outer covering having been removed to disclose the hanging 'combs' of cells in which the young are reared. (1) The tunnel through which the wasps come and go. (2) The root from which the nest hangs. (3) The cavity excavated and enlarged by the wasps to accommodate the nest. (4) The entrance to the nest proper



Humble-bee casts. (*Left*) Queen ; (*right*) Worker ; (*below*) Male or Drone



(a)

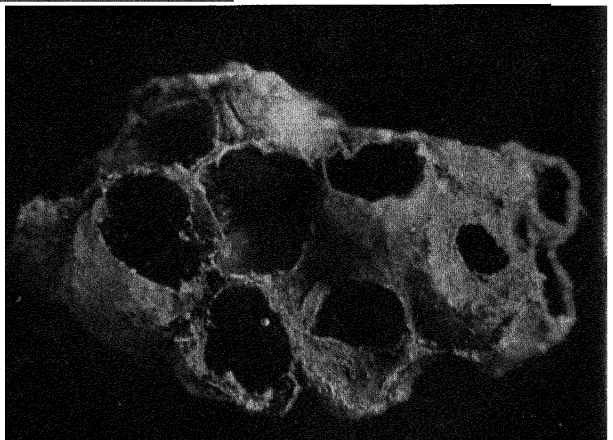
(b)

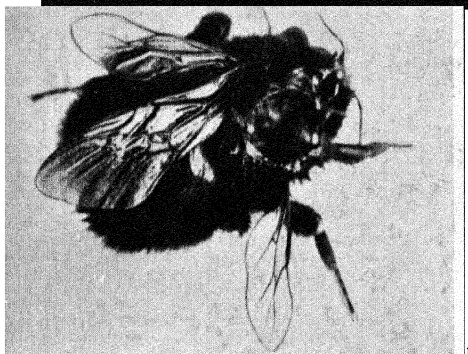
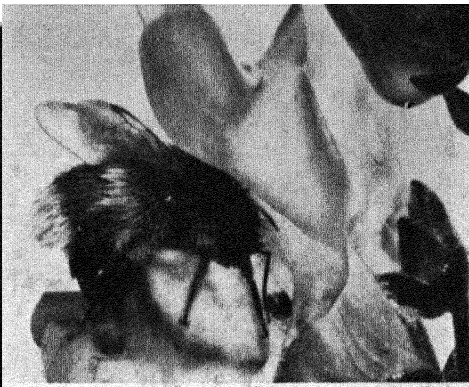
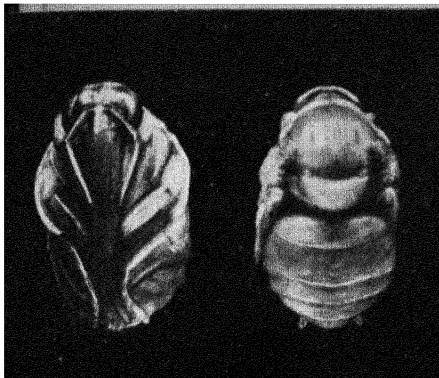
Plate X
 THE HOUSEKEEPING
 OF THE HUMBLE-BEE
 (Chapter 5)

(*Left, a*) Loaded 'pollen basket' on the hind leg of a Humble-bee

(*Left, b*) The same with the load removed

Humble-bee's honey pots. Some are old cocoons patched up where necessary with wax. One—to the right—is made entirely of wax



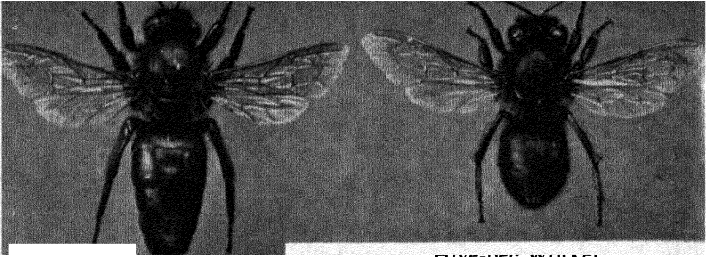


(*Top, left*) Pupae of Humble-bee, left vertical, right horizontal. (*Top, right*) Humble-bee visiting a snapdragon flower. (*Bottom, left*) Killed by great tit, which has made a hole in the thorax to get at the honey crop. (*Bottom, right*) Five half-grown larvae of the Humble-bee under their protecting dome of wax

Plate XI. HOUSEKEEPING OF THE HUMBLE-BEE (Chapter 5)

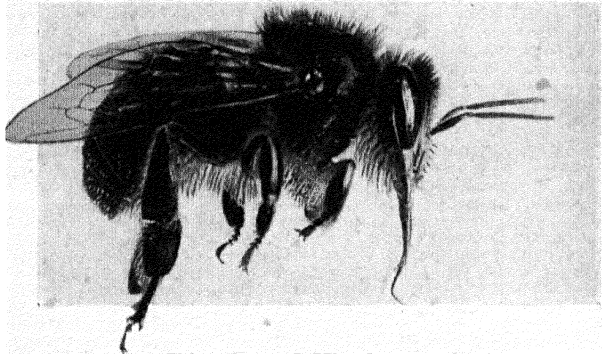
Interior of a Carder Humble-bee's nest. N.B.—The empty snail shell (*right*) happened to be there when the Queen started to build





Hive-bee Queen

HIVE-BEE WORKER

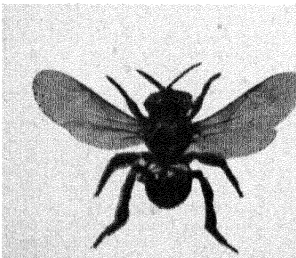
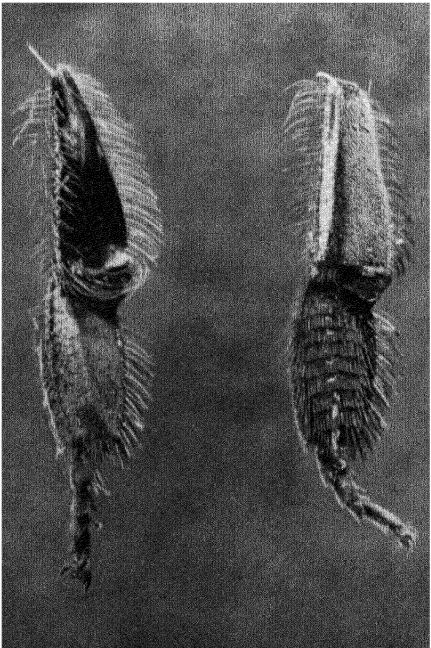


Side view of Hive-bee worker magnified. Note long 'tongue' and enlarged tarsal joints of hind-legs

Plate XII
MOSQUITO BEES AND
HIVE-BEES
(Chapter 6)

(Above) Resinous entrance tube to the nest of the bee *Trigona collina* from Singapore. It stood out from the trunk of tree in which the nest was built

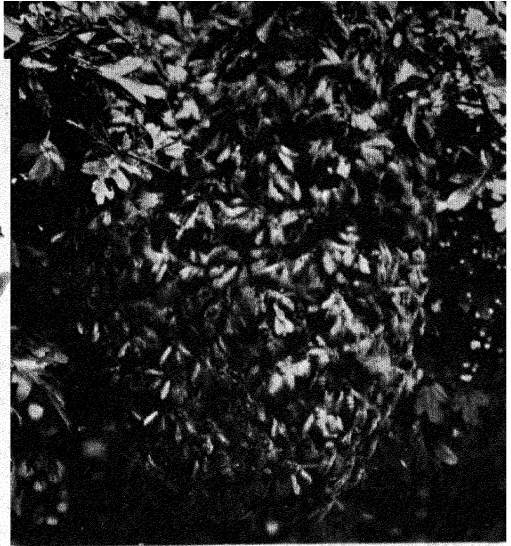
(Right) A Hive-bee's hind legs showing, left, the 'basket' on the outside, and, right, the pollen combs on the inside



Mosquito Bee
Trigona sp.)

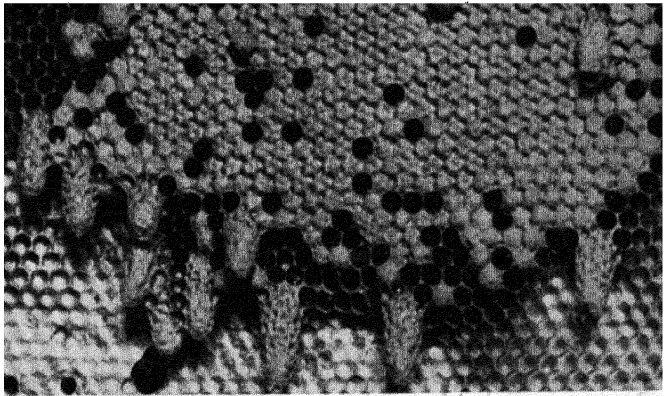


Hive-bee returning from a foraging flight with loads of pollen on the 'baskets' of the hind legs



A prize swarm of Hive-bees in June suspended in a hawthorn hedge

Brood comb of the Hive-bee with large thimble-shaped royal cells in which prospective queens are reared



An old-world apiary of 'skep' hives covered and protected in readiness for winter

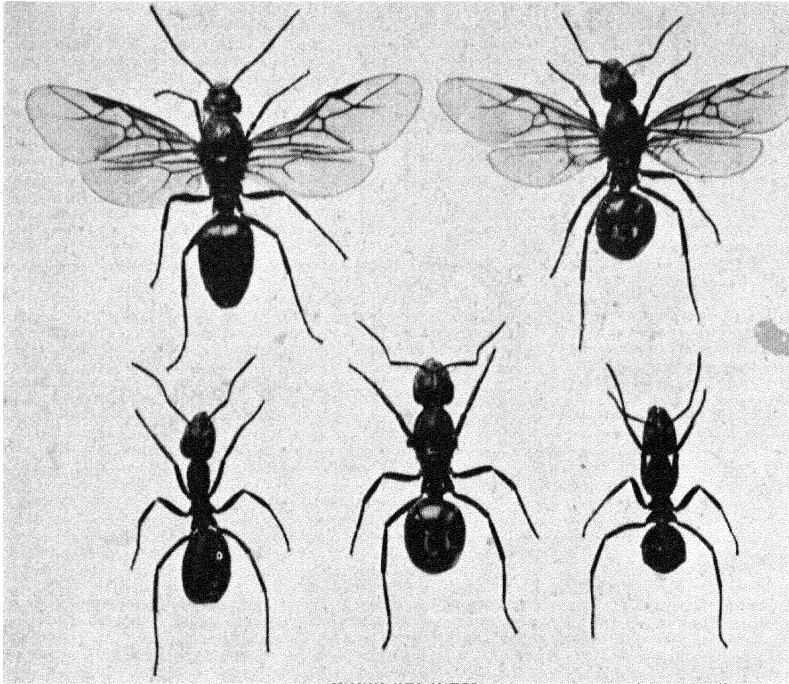


Plate XIII
MOSQUITO BEES
AND HIVE-BEES
(Chapter 6)



Larvae of Wood-ant

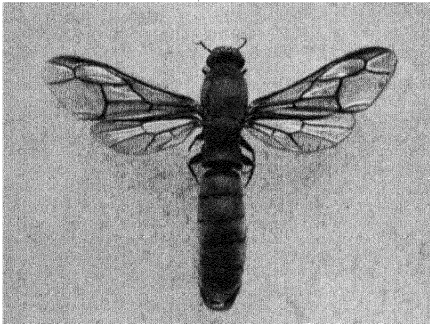
Cocoons of Wood-ant



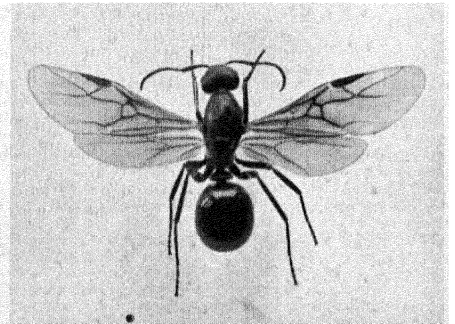
wood-ant types

(Top, left) Male. (Top, right) Female. (Bottom, left) Worker—large.
(Centre) Queen—after shedding wings. (Bottom, right) Worker—small

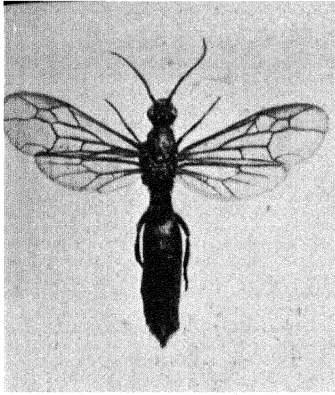
Plate XIV. ANTS (Chapter 7)



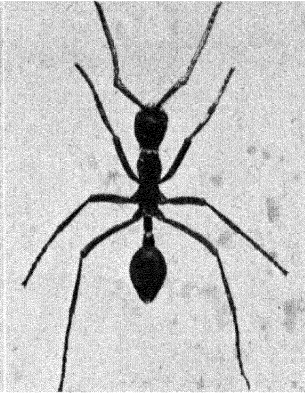
Driver Ant (*Dorylus nigricans*)
Winged Male



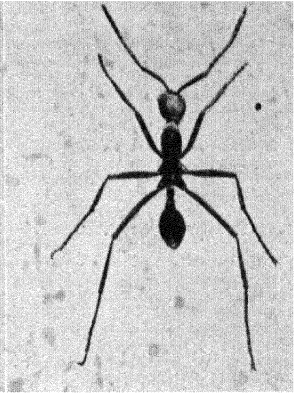
Wood-Ant (*Formica rufa*)
Winged Female at time of swarming



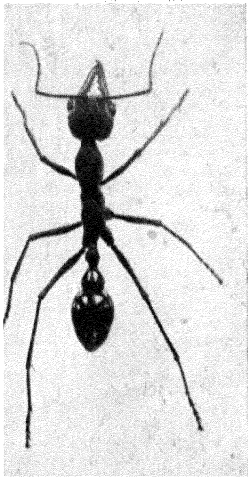
Winged form (*Eciton*)



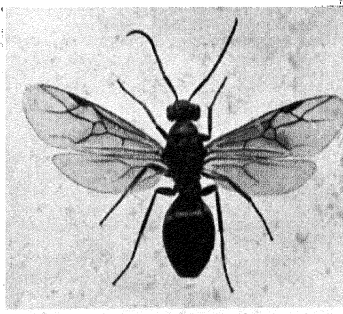
Foraging Ants
Large 'Worker'
(*Eciton* sp.)



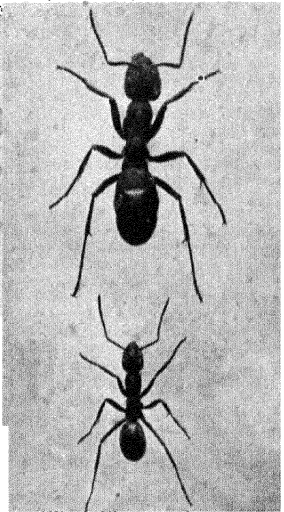
Small 'Worker'
(*Eciton oapax*)



Bulldog Ant
(*Myrmecia gulosa*)

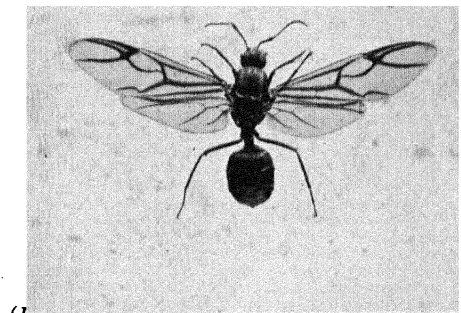
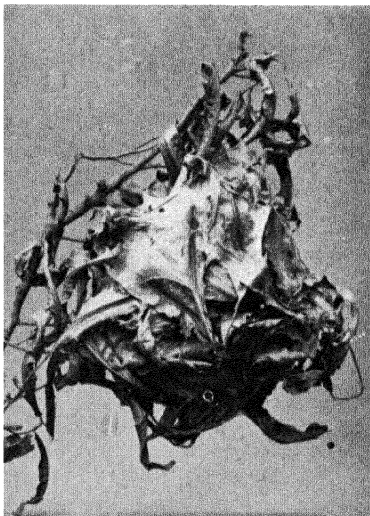


Wood Ant (*Formica rufa*)
Winged Male at time of swarming



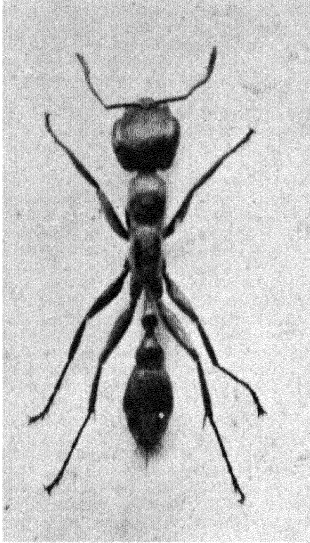
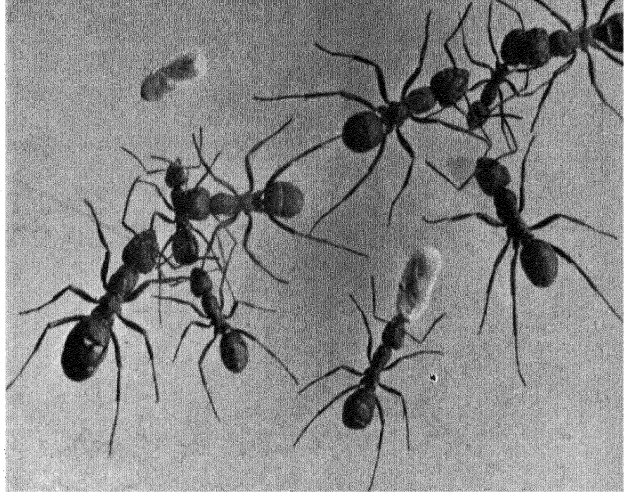
(Top) Slave-making
Ant (worker). Negro
Ant (worker), the
enslaved (below)

Plate XV
ANTS
(Chapter 7)

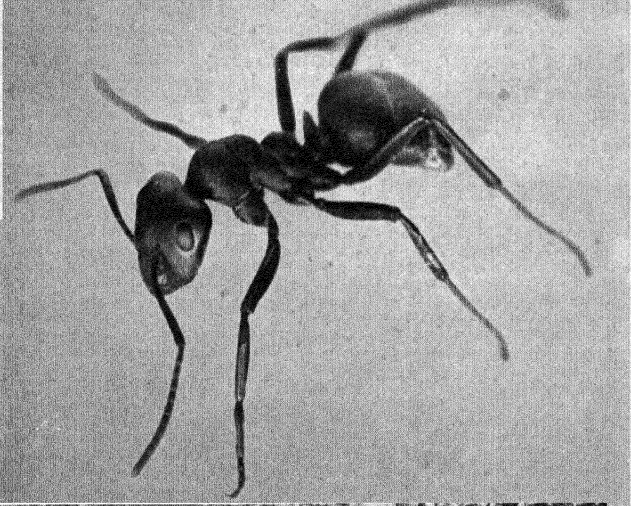


(Left) Nest of the Spinning Ant (*Ecophyga smaragdina*) made by using the larvae to bind leaves together (see text)
(Above) Winged female of the Spinning Ant
British Museum (Natural History)

(Right) Slave-making
Ants, (*Formica sanguinea*), attacking the
smaller enslaved species
(*Formica fusca*) and
carrying off cocoons



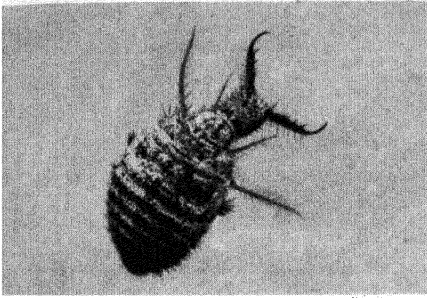
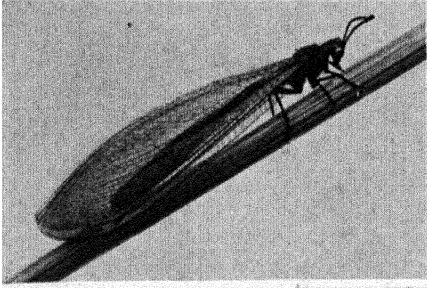
(Below) Worker Wood-ant, magnified to show detail



(Above) *Pseudomyrma
bicolor* enormously
enlarged—the ant
which lives in the hol-
low thorns of the
Bull's-horn Acacia



Plate XVI
ANTS
(Chapter 7)



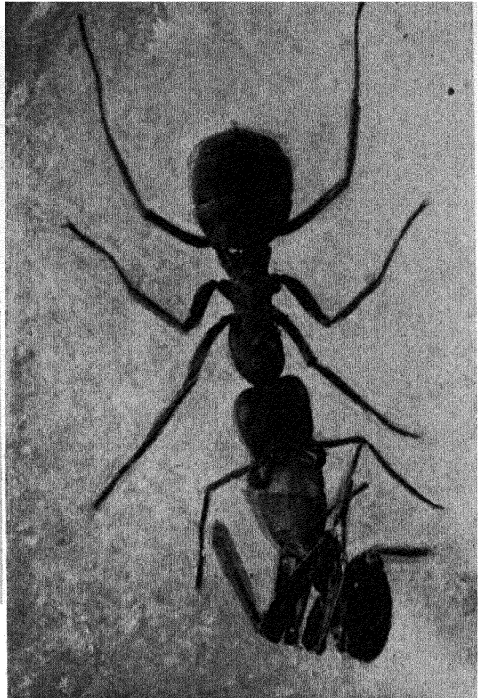
An enemy of Ants
 (Top) Adult Ant-lion
 (Below) Ant-lion's larva

Plate XVII

ANTS

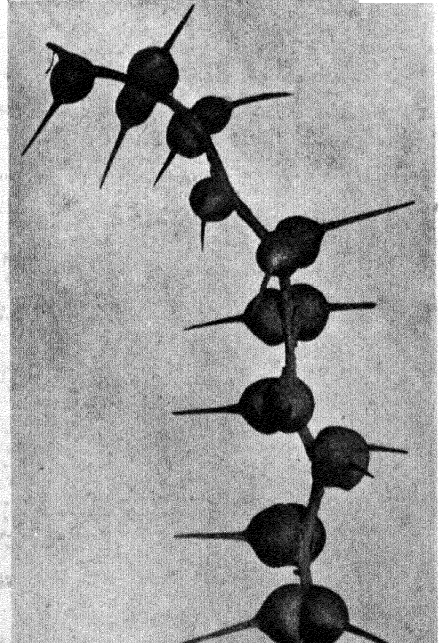
(Chapter 7)

Central American 'Bull's-horn Acacia' (*A. sphaerocephala*), in whose thorns the ants (*Pseudomyrma bicolor*) live



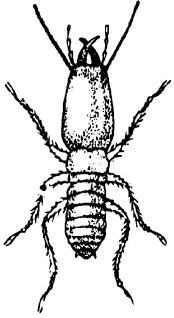
Wood-ant worker carrying the dead and shrivelled body of a nest-mate to the place of burial

Twig of African *Acacia fistulosa* whose thorns are inhabited by ants of the genus *Cremastogaster*



TYPES OF
TERMITES

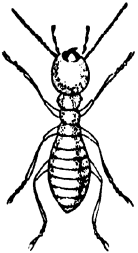
Plate XVIII. TERMITES OR WHITE ANTS (Chapter 8)



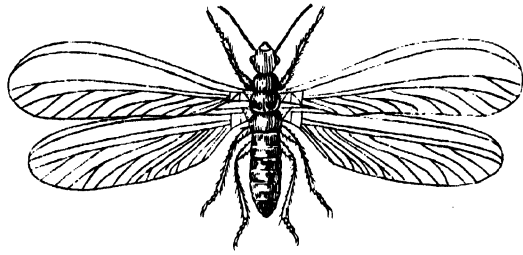
Soldier



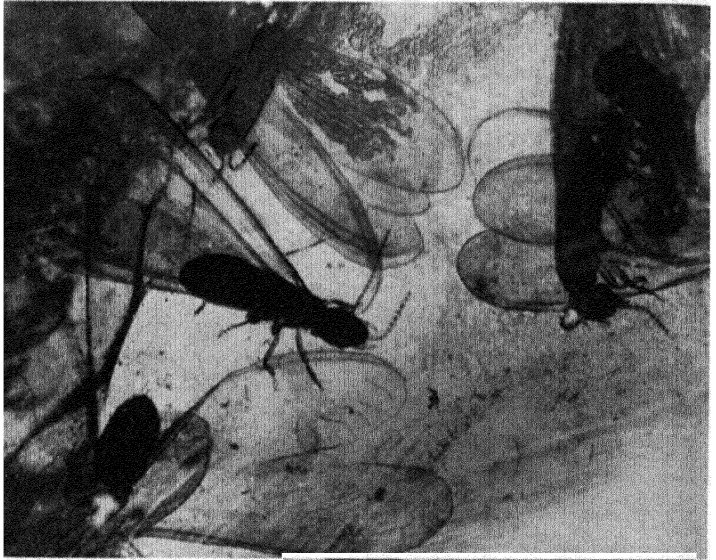
Reserve Female



Worker



Winged Male

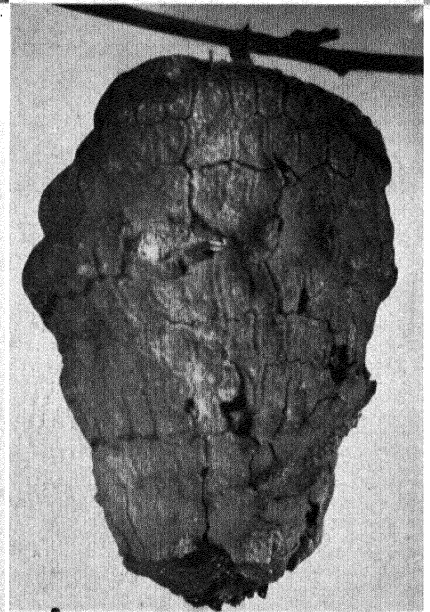


Termites in amber

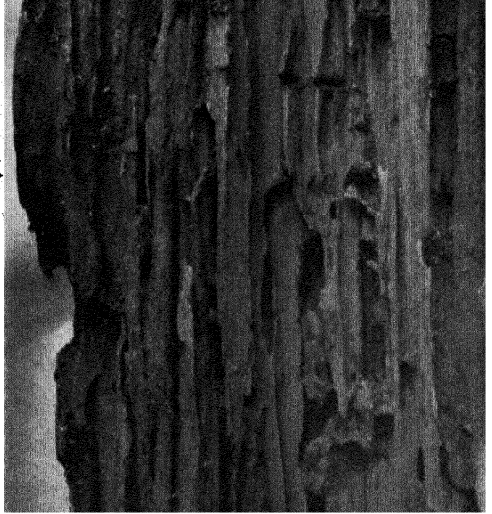
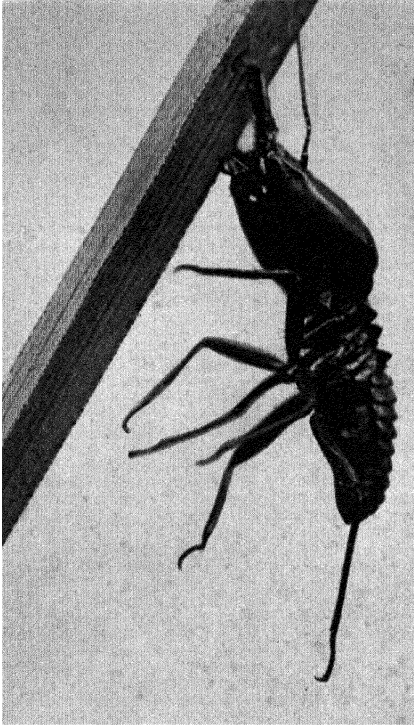
White-
ants' nest
from
Sierra
Leone.
Height
10½ inches



British Museum (Natural History)



Arboreal nest of a species
of Termite



Wood eaten by Termites

(Left) Grass-cutting Termite, a soldier, holding on to a piece of grass stem

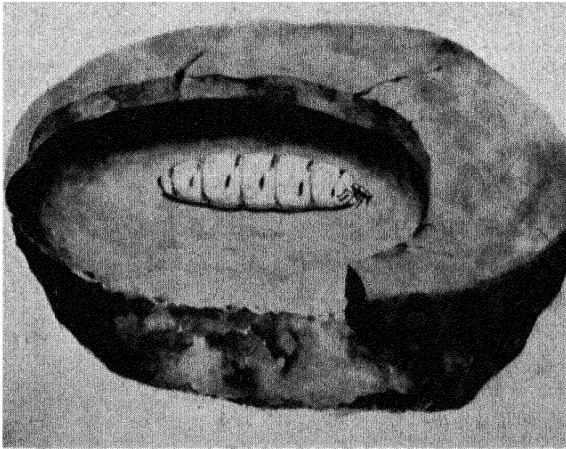
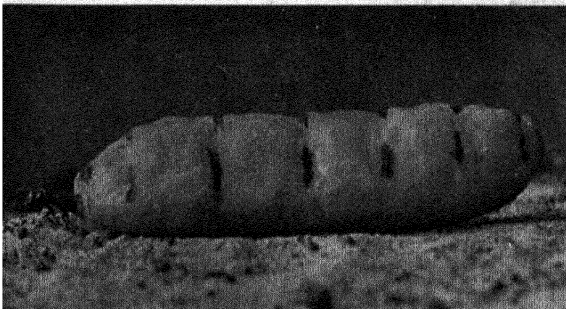


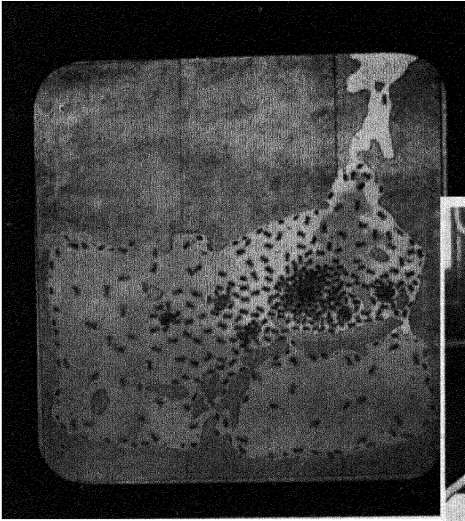
Plate XIX
TERMITES OR
WHITE ANTS
(Chapter 8)

Termites' Royal Cell
broken open to show
the reigning queen

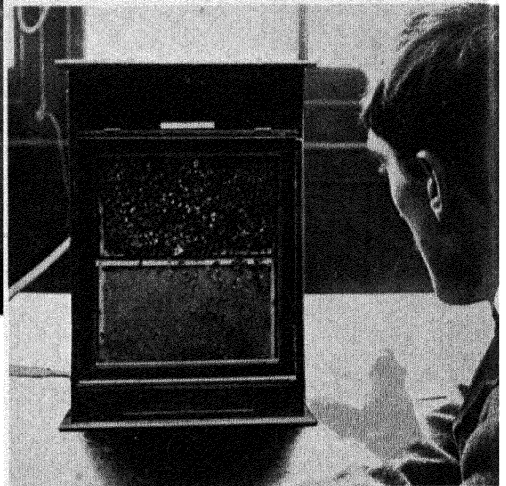


Fertile female Termite,
or Queen. Note that
the abdomen is
immensely swollen

Plate XX
SOCIAL INSECTS AS PETS
(Chapter 9)

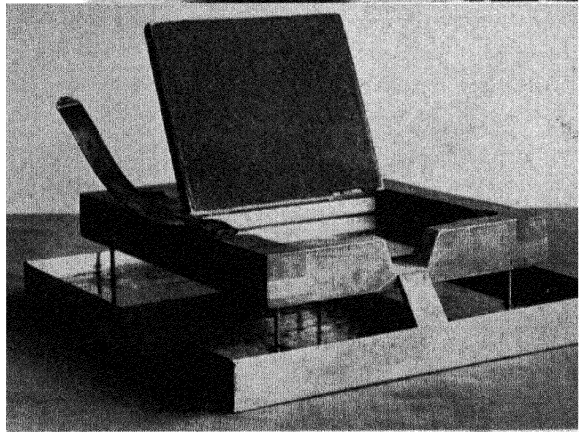


(Above) Lubbock Formicarium

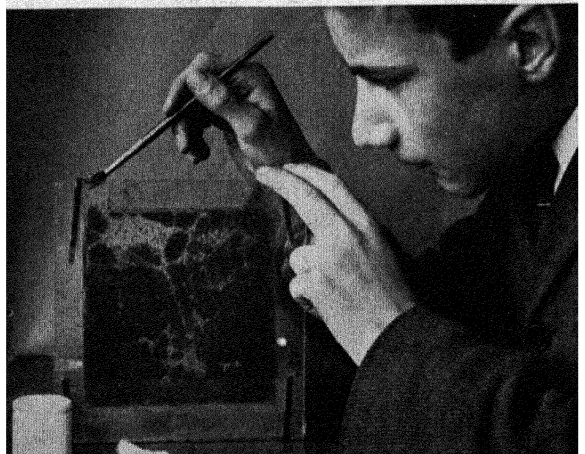


(Right) Watching bees in an observation hive (see text)

A photographic printing frame converted into a formicarium or observation nest for ants (see text)



Feeding ants in a Lubbock Formicarium with a little honey



bees may often be seen lying in considerable numbers. "These (states Edward Saunders) have been caught, after they have filled themselves with honey, and become torpid in consequence, by the great tomtit and possibly other birds. The bird pecks a hole in the insect's thorax, enjoys the honey it has eaten and then drops the quivering body to the ground. I once had the opportunity of seeing this slaughter going on, and was able to detect the great tomtit as the murderer."

Several kinds of two-winged flies pass the early stages of their metamorphosis in humble-bees' nests. In some instances the perfect insects resemble their "hosts" in appearance to a remarkable degree. The humble-bee fly occurs in two distinct colour-varieties, one red-tailed, the other yellow-banded, each of which might be mistaken for a different "model"—as the mimicked species is termed. These flies are allowed to come and go unmolested by the bees, their larvae playing the part of scavengers in the nests. The same seems to be true of the carder-bee fly, which is an almost perfect copy of its namesake, and has a similar mode of flight. The larvae of other flies belonging to a small sub-family (*Conopinae*) are abdominal parasites of humble-bees. The eggs, which are furnished with minute hooked processes at one end, are said to be attached by the female to the host during flight. The pupa is formed at the end of the season in the latter's body, and remains there until the spring. In build and coloration the perfect insects are not in the least bee-like, but some are specious imitations of small solitary wasps.

The green-shaded honey-moth is another enemy of humble-bees which in some seasons works considerable havoc. The females are active during the summer months, and make their way into the nests to lay their numerous eggs. The family of caterpillars, which may number several hundred, spin silken galleries among the bees' cocoons, and are said to be honey-feeders; but this is questionable. More probably their food consists chiefly of vegetable substances, since—as we have seen—they are quite often found in wasps' nests, as well as under decaying bark, in neither of which situations is honey available. The mature caterpillars leave the nests before spinning their cocoons.

One of the so-called velvet-ants—the largest of our several British species—is an ichneumon parasite of humble-bees. As

the popular name suggests, the body of these insects is clothed with a dense pile of short hairs, and in the present species the colouring is decidedly showy, the thorax being rust-red, while the abdomen is banded in yellow and black. Only the male has wings. The sturdily built female, whose length is about three-quarters of an inch, makes her way into a humble-bees' nest and implants her eggs in the developing grubs, at whose expense her own larvae are nourished. She is said also to pilfer the bees' honey, although her normal predilections are predacious. Happily for British humble-bees this insect is a rarity with us; but a Danish entomologist records the case of a humble-bees' nest containing nearly eighty cocoons, seventy-six of which produced velvet-ants instead of bees!

Slow but certain ruin descends upon a humble-bees' community in which a cuckoo succeeds in establishing herself. These insidious parasites are themselves authentic humble-bees and often resemble their dupes in appearance so closely that only by detailed scrutiny can they be told apart. One species, for example, is almost indistinguishable when on the wing from its red-tailed counterpart, save that it is slightly larger on the average and hums more softly. But at rest on a thistle-head its wings are seen to be smoky in hue, instead of pale amber-coloured, while its hind-legs lack those insignia of honest industry—the “combs” and “baskets” for harvesting pollen.

These cuckoo humble-bees infest chiefly the subterranean species. They have no social life of their own, occurring only as males and females. The entry of one of the latter into a nest at first arouses alarm and resentment among its worker population, but strangely enough harmony is soon restored, and eventually the rightful queen is stung to death by the intruder. She proves herself a shiftless substitute, of slovenly habits, making no contribution to the maintenance of the community. On the contrary, not only are the grubs that hatch from her eggs fed and tended by the credulous workers, but when the alien adults appear they consume much nectar from the common store, which they do nothing to replenish. In the end these offspring score a despicable triumph, for with the coming of autumn they leave the ravaged nest, and the females—after pairing—go into hiding ready, the following spring, to carry on the nefarious practices of their breed.

Chapter Six

MOSQUITO-BEES AND HIVE-BEES

THE large family of tropical and sub-tropical stingless bees—often called mosquito-bees because many of them are quite tiny—appear in certain respects to form a connecting link between the humble-bees and the hive-bees, although our knowledge of their life-histories and habits is still far from complete. The species are very numerous. Most of the two hundred odd which have already been described are grouped in the genera *Melipona* and *Trigona*. Members of the former are confined to South America, but those of the latter are found also in the Old World. They usually nest in hollow trees, in the crevices of rocks or stonework, or in holes in the ground. A few build in deserted ant-mounds, while one species is said always to locate its brood-comb in a termites' habitation. Wax, which is extensively used, is produced only from the upper side of the abdomen; but the workers spend much time in collecting clay, and employ it to barricade their nest against possible intruders, except for a small orifice for entrance and exit—and even this is guarded by sentinels. Thus, to quote H. W. Bates, these bees have learnt to be “masons as well as workers in wax and pollen-gatherers”. Some of them, especially those of the Eastern Hemisphere, collect resin for constructional purposes, and in some instances provide the nest with a long, spout-like vestibule of this material, its interior being kept in a sticky state, presumably to embarrass unbidden guests. So large is the quantity of resin accumulated by these insects that it has acquired a commercial value, being sold under the trade name of “dammar” for the manufacture of varnish and other purposes.

Stingless bees have several varieties of architectural practice. Generally speaking the cavity chosen as a residence is divided into two chambers, one for the accommodation of the brood, the other to be used as a store-room for honey and pollen. Usually the combs of waxen cells—all of which open upwards—are in horizontal tiers, supported one above the other on little pillars,

with gaps here and there for the passage of the nurse-bees, perhaps also to serve as ventilating shafts. Nests of another type are built by some Australian stingless bees known locally as "karbi". In this case the combs are arranged like an irregular, spiral staircase, tapering towards the ends and encased in wax, with a labyrinth of passages on its outside. Still other species—presumably less skilful or more careless—construct no regular combs, but pack their cells together in uncovered clusters or heaps.

The range of size covered by the bees of this family is remarkable. Of the forty-five species found by Bates during his travels in the Amazon Valley the largest measured one-half and the smallest barely one-twelfth of an inch in length. So far as is known a colony always consists of the usual three grades, but the workers and fertile females are more definitely differentiated than those of the humble-bees. It is said that the drones sometimes take part in the labours and defence of the community, although they are not structurally adapted for collecting and carrying pollen, while there is reason for thinking that more than one reigning queen may be tolerated in the nest at the same time. The method of rearing the grubs resembles that practised by most solitary bees, a complete ration of pollen and honey being placed with the egg in the cell, which is then sealed over ; so that there is no actual contact between the workers and the brood as is the case with other social insects.

Since an established community comprises eventually enormous numbers of individuals, large stores of honey are amassed, as much as two quarts being taken from a nest of average size which Bates saw opened. According to Dr. Richards the Maya Indians domesticated some of these bees long before the Spanish conquest of Mexico, housing them in hollow logs and regarding these primitive apiaries as an important part of their owner's property. The honey was removed from the hives bi-annually, about three and a half liquid pints being obtained on each occasion. But these amounts seem small compared with the 50 lb. yielded by an Australian nest of exceptional size.

The reason why these bees do not sting is that the apparatus which would enable them to do so is defectively developed while the dart is blunt at the tip ; but they make up for their deficiency by

fighting desperately with their jaws, and are said to smear their enemies with a noxious, sticky substance. The tiny kinds are apt to make themselves a nuisance by getting into the eyes, mouths and nostrils of persons walking or resting in the vicinity of their haunts. As the queens lack the equipment necessary for pollen-collecting and cell-making they are unable to found fresh colonies unaided. Hence, these must always result from swarming. Detailed information is still needed, but a swarm is probably led, not by the ageing queen, but by a young, newly impregnated female. The way in which the castes are brought into being is still obscure. Because the cells are provisioned once for all and sealed up after the egg is laid, this can hardly be due to differential feeding, such as is practised by hive-bees. Perhaps it depends entirely upon hereditary factors, as seems to be the case among some other groups of social insects.

Nobody knows for certain where the domesticated hive-bee or honey-bee originated, but in all likelihood this was somewhere in the Indo-Malayan region which—excepting a tropical African species known as Adamson's bee—is the only part of the world where bees of this kind occur in a truly wild state, these being the giant bee, the little bee and the dinger or native Indian bee. This supposition seems all the more probable in view of the exceptionally close relationship of our hive-bees in their several varieties to other members of the genus *Apis*—especially the Eastern or Indian bee—and their remarkable readiness to hybridize. Indeed, the hive-bee as it exists today is almost certainly the multi-racial product of prolonged interbreeding, its remote ancestors having been domesticated in prehistoric times, possibly by the ancient Egyptians as long ago as 3,500 B.C. Thanks to the fact that it has learnt to keep its nest sufficiently warm in winter to withstand fairly hard frosts, to gather its sustenance from a wide variety of flowers, and to lay up a reserve of honey to tide it over the period when none can be garnered, it has been able—with some human assistance—to adapt itself to all but the most rigorous climatic conditions, and during the last two centuries has been carried about by civilized mankind in his wanderings, so that its distribution is now well-nigh cosmopolitan.

Seven distinct races of the hive-bee are said by Dr. S. B. Whitehead to be used for honey-getting in the British Isles. Of

these the first in the field was the so-called "British black bee", named *Apis domestica* by John Ray, the English naturalist of the seventeenth century. "Its good qualities are its longevity, its willingness to work when weather conditions are poor, and its ability to cap the cells of the comb perfectly. These qualities are offset by its vulnerability to disease, probably because it is a poor cleaner and scavenger of the hive, and lacks aggressiveness in defending it." But it has become so intercrossed with other imported races that a pure strain is seldom procurable. Of these imported races one of the best is the Ligurian or Italian bee, a sweet-tempered, disease-resistant strain, highly esteemed by beekeepers of the Northern Hemisphere—although, originating as it did in a warm region, it is somewhat lacking in hardiness and needs special protection during the winter months in cold districts. The merits and demerits of four other races of bees may be briefly summarized as follows :

Dutch bees, usually greyish in colour, were largely imported after the First World War to replace colonies that had been lost through disease, and very many stocks now in this country have some Dutch in their ancestry. The race is prolific, hardy and active, but somewhat uncertain in temper and given to excessive swarming.

Prior to the Second World War French bees were freely imported. They are of the European brown type but vary in character and performance according to the district from which they come. The best strains are hardy, prolific and easy to handle.

The large, greyish-black Carniolan bees have a good reputation, being prolific, hardy and docile ; also, they cover their honey-cells with a fine white capping. But they defend their hive poorly against marauders and are too much addicted to swarming.

Cyprian bees, like Italian bees and all other races originating in warm regions, are more or less golden-orange in colouring. "They are said to be of a vicious temper if of pure type, but crosses have produced a strain that is of good quality. Their chief fault is that they leave no air-space under their cappings when sealing honey-cells. Consequently, the cappings become wet and dark-coloured, and are of poor appearance for honey sections."

The economy of the hive-bee, both from the standpoint of the biologist and that of the practical bee-keeper, has been studied so

closely and dealt with at length by so many able writers that only a brief recapitulation of the more salient and interesting facts need be given here. Readers desiring more detailed information may consult such works as those of T. W. Cowan, Tickner Edwardes and Maurice Maeterlinck among the older writers, and those of more recent publication by Colin Butler, Gilbert Nixon and S. B. Whitehead—to mention only a few of the readily available sources.

Contrary to popular belief, the reigning queen of a hive exercises no prescriptive authority or control over her subjects. Their attachment to her person used to be ascribed vaguely to “instinct”. But long-continued observation and experiment have enabled Dr. Colin Butler, of the Rothamstead Research Station in Hertfordshire, to demonstrate that the secret of her attraction for her vast family of workers is their relish for a peculiar secretion that they lick from the surface of her body, particularly the abdomen. This “queen substance”, as it has been called, can be rubbed off with cotton-wool, which afterwards is as attractive to the workers as the queen herself. So long as this mystical essence is available the affairs of the hive are smoothly conducted; but when, owing to illness or advancing age, the queen’s supply shows signs of failing, the workers begin immediately to build the large thimble-shaped cells in which princesses or potential queens are reared.

For one of his experiments Dr. Butler removed the authentic queens from three glass-sided observation hives. He then confined a queen in a tiny wire-gauze cage through the meshes of which she could be licked by the workers. The first hive was allowed to have the queen for fifty-two minutes out of every hour, the second for only six minutes during the same period, while the third did not have her at all. Two days later the workers in the first hive—evidently detecting a slight falling off in the supply of “queen substance”—had built three queen cells, those in the second ten, and those in the third twenty-seven.

Functionally considered, the queen is just a highly specialized egg-laying mechanism, fed and tended by the workers, and physically incapable of taking part in their labours. They alone gather pollen and nectar, secrete wax for comb-building, and perform the many other tasks requisite for the well-being of the

community. When supplies of wax are in request a number of the younger bees gorge themselves with honey and hang together in a dense festoon until tiny, semi-transparent flakes of this material issue from between the ventral plates of their abdomens. These are first chewed up with the insects' saliva and then moulded with their jaws into the six-sided cells of which the comb consists. Cells which are used as cradles for rearing workers or for storing honey measure about one-fifth of an inch in width at the narrowest diameter—that is, between two parallel sides. Drone cells are larger—about one quarter of an inch in diameter, whilst massive thimble-shaped cells with their openings downwards are constructed for rearing princesses or potential queens.

As wax is produced by the bees at the expense of honey, beekeepers long ago hit upon the device of supplying their stocks with what is known as "comb foundation"—i.e. sheets of pure beeswax, obtained from old combs melted down and freed from impurities, then rolled by machinery into plates of the required thickness, embossed in imitation of natural cell-bases. The bees do the rest by softening and pulling the wax into shape, and are so saved the expenditure of energy involved in wax-making—to say nothing of the gain to the owner, since to construct one pound of comb at least six pounds of honey will be consumed. The comb is suspended from the upper part of the frame—or from the roof of the old-fashioned skep hive—and when complete is often fixed at the sides and bottom by means of special attachment cells having four, or perhaps five, sides instead of the normal six. Transition-cells, as they are called, are often made where worker-cells unite with drone-cells, or vice versa. A comb consists of two series of cells set back to back in such a way that the base of one is formed by the juncture of the three cell-bases immediately behind. In this manner a considerable economy of material and labour is effected, while each cell is given a slight upward tilt which prevents the honey from spilling out while it is being filled and before it has been capped.

The reigning queen of the hive lays a tiny, white, sickle-shaped egg, weighing approximately 0·132 mg., at the bottom of each brood-cell. In about three days this hatches, and thereafter the bee-baby is said to be visited and fed by the workers not less than 1,300 times in each twenty-four hours, so that in five days its

weight increases 230 times and its size 1,570 times. Drone larvae continue to grow for six days before the cells are sealed down, after which the inmates begin to spin their cocoons. Worker larvae spend two days, drones three, and princesses only one in completing this task—which, after all, is little more than a formality dating from the days when the youngsters had no nurses to guard them during the succeeding period of quiescence and pupation. Granted favourable climatic conditions, the number of days needed for the completion of the life-cycle—egg to perfect insect—is as follows: worker twenty-one, drone twenty-four, princess fifteen. These varying speeds of development are directly related to the importance of the three castes as members of the community. The princesses, as potential queens, are essential as foundresses, but they cannot function without the workers, while the perpetuation of the species depends ultimately upon the drones, which in all other respects must be regarded as parasites, living on the bounty of their colony.

The factors which determine the three castes of the hive's population were for long shrouded in mystery. It is now known that the queen controls the sex of the eggs that she lays, unfertilized eggs producing drones, fertilized eggs females. Whether the latter develop into workers or princesses seems to depend mainly upon the nurture and feeding of the resulting larvae. Experiments have shown that if eggs or very young larvae are transferred from worker cells to the more roomy queen cells, where they are given a special diet, they become princesses.

On her emergence from her nursery-cell the adult worker bee is at first weak and inexperienced. For a fortnight or so most of her energy is devoted to cleaning and feeding her younger sisters, the grubs. Then she may take part in secreting wax, comb-building, cleaning the hive and guarding its entrance. During the summer months her life-span is unlikely to exceed six weeks, the last two or three of which she spends chiefly in foraging flights, bringing home supplies of pollen and nectar. The number of plants, both wild and cultivated, whose flowers are visited by hive-bees in Britain is astonishing. Whitehead enumerates upward of 150 species in tabular form, giving the colour, relative value, etc., of the pollen and nectar obtainable from each. In this country the three principal "honey flows" occur during the spring,

summer and autumn, being marked respectively by the blossoming of fruit trees, clovers and heaths. Early sources of pollen are the flowers of such plants as winter aconite, snowdrop, crocus, scilla and narcissus, and those of certain trees, especially hazel, elms and willow. Generally speaking, the abundance or paucity of the seed-yield is proportionate to the attention paid by insects, and in particular by bees, to the plants in question. Occasionally, in seasons when nectar is scarce, hive-bees collect the substance known as "honey-dew"—the sweet, sticky secretion of aphides or plant-lice. This is unwholesome, and apt to cause dysentery among the brood. Combs with much honey-dew in them are therefore withdrawn by experienced apiarists during the autumn examination of the hive, the loss being made good with sugar syrup.

As we have seen, a bee carries home pollen piled up on the "baskets" of her hind-legs. If she has been gathering nectar she may have as much as half her own weight of it in her crop. Although the two terms are often used synonymously, "nectar" and "honey" are not identical. The former is sucked from flowers, and while being conveyed to the hive is mixed with certain enzymes secreted by the insect's glands which convert its raw sugars into the dextrose and laevulose of honey. Furthermore, when this product is brought into the hive it is transferred to the crop of a younger worker which spends some minutes sucking it in and out over the surface of her tongue before discharging it drop by drop into a cell. It has been estimated that one pound of honey harvested and processed in this way represents 37,000 separate flights, each occupying a bee for thirty-five minutes to an hour, according to the distance flown and the weather conditions prevailing. The so-called "bee-bread", which has good keeping qualities, consists of pollen with a small admixture of honey. It, too, is stored in cells which—like those containing honey—may be sealed with waxen caps when they are full; but fresh pollen is preferred for feeding, and is gathered whenever possible. It is the bees' source of protein, and without it the life of the workers is very much shortened and the brood cannot be successfully reared.

Besides nectar and pollen, hive-bees collect three other substances, namely, propolis, balm and water. Propolis is a kind of resin obtained from the buds of plants, especially trees. It is used

to stop up crevices and to encase some objectionable object, such as the carcase of a slug or a mouse, which is too heavy for the bees to remove. Balm—applied as a varnish to the inside of the cells before eggs are laid in them—is perhaps a specially liquid and transparent variety of propolis, but whence it is gathered, or whether, in fact, it is secreted by the bees themselves, is at present uncertain. In hot, dry climates, and throughout the summer in temperate regions, water is in constant demand, and is apparently needed in the hive to cool the air by evaporation and to maintain the degree of humidity necessary for the well-being of the brood.

In warm weather bees practise a remarkable system of fanning with their wings by means of which air is drawn in at one side of the entrance to the hive and driven out at the other, after circulating through all the interstices between the combs. Of the many workers engaged in this duty each agitates its wings for about a minute, after which another takes its place and starts fanning, to be followed by a third, and so on until the interior of the hive has been ventilated to the insects' satisfaction.

Queens have been known to lay eggs at the rate of from 5,000 to 7,000 per day over a short period, but the more usual number is between 1,500 and 2,000. Hence, as the season advances the worker population of the hive tends to become greater than the space available can accommodate, and preparations are made for swarming—although the incentive to this is by no means always the threat of overcrowding. In all likelihood the “swarming impulse” is an integral part of the instinctive legacy inherited by the bees from their remote ancestry, and is likely to assert itself whenever atmospheric and other conditions are favourable. On these occasions the reigning queen becomes greatly excited and the ordinary routine of the community comes temporarily to a standstill, while many of the workers flock to the storage cells and gorge themselves with honey, as if aware that an exhausting adventure lies ahead of them. Scouts are then sent out to explore the neighbourhood: and soon a dense cloud of bees, headed by the queen, issues from the hive, and after flying round for a time settles in a cluster on the branch of a tree, or some other convenient resting-place. The bees composing the swarm do not return to their old quarters, but—led by the queen—eventually found a fresh community. An alert apiarist will make haste to “take the

swarm"—i.e. induce it to occupy a new hive made ready for its reception. But if for any reason the bees are left to their own devices they will sooner or later find a home for themselves in the hollow trunk of a tree, among the rafters of a shed or outhouse, or in some similar sheltered situation. Hive-bees in all their many races have a marked tendency to nest in dark cavities. As soon as a swarm is housed to its liking the workers begin to secrete wax-scales and to construct combs, in some of which the queen lays eggs, while others are reserved for the storage of pollen and honey, which foraging parties set out to gather. Thus, in the course of a few days, an independent and thriving colony is brought into being. A large swarm may consist of 30,000 individuals, while the population of a strong, well-established hive may number 50,000 to 80,000.

A prime or first swarm of the season is invariably led by the reigning queen of the hive, and almost always chooses the mid-morning of a warm, sunny day for its exodus. If a second swarm occurs later in the year the workers are accompanied by a young princess which later mates with a drone—the reigning fertilized queen remaining in the hive.

As soon as a swarm has left a hive the workers which remain liberate one of the young princesses that up to this time have been kept prisoners in their cells. Her first act on being freed is to tear open the rest of the royal cells and sting all her sisters to death. This seems an appallingly savage act ; but the unwritten law of the hive decrees that one queen only shall be allowed to reign. About a week after this massacre the victorious princess—or, as she must now be called, the queen elect—leaves the hive for her nuptial flight, followed by a bevy of eager drones, with one of which—or with one from a neighbouring colony—she pairs, high up in the sunlit air. In this way she receives into a special pouch—the spermatheca—a sufficiency of semen to last for the whole of her procreant life, which in the most favourable circumstances may extend to five years. The successful drone dies in the act of copulation, but the fertilized queen returns to her hive and settles down to her task of egg-laying, which continues without a break—except in the dead of winter or if she herself heads a swarm—until the day of her death. The superfluous drones, which have no stings and so cannot defend themselves, are treated with scant

ceremony, being either set upon and killed by the workers, or else driven from the hive to perish from cold and hunger.

Until comparatively recent years almost nothing was known concerning what, for want of a more precise term, we may call bee-psychology, or how information is circulated among the members of a community. Much in this field of research remains mysterious, but during the past half century some striking discoveries have been made, not only by scientific investigators, but also by practical apiarists intent on promoting the best interests of their stocks. Writing of the behaviour of hive-bees, Dr. S. B. Whitehead remarks that "not only does each colony have individuality—some work earlier or longer than others, some have shorter tempers, some are better comb-builders—but despite the regimentation of the bee community as a whole, individual bees are capable of exhibiting personality". This estimate is borne out by the results of experiments devised by Dr. Colin Butler which indicate that bees have varying degrees of educability. It seems that these insects rely upon a sense of touch to find their way about in the total darkness of the hive's interior. A simple maze was accordingly arranged with several blind alleys and a dish of syrup placed at its focus. Many bees quickly reached the dainty, but a number took longer—some much longer—to discover the direct route.

As the result of long-continued observation the Rev. Tickner Edwardes concluded that the worker hive-bee has to learn her business of foraging step by step. "Her first experiences are a succession of blunders. She appears not to know for certain where to look for the coveted sweets, and can be seen industriously searching the most unlikely places—crevices in walls, tufts of grass, or the leaves of a plant instead of its flowers. The fact that the nectar is hidden deep down in the cup of the flower, beyond its pollen-bearing mechanism, seems to dawn upon her only after much thought and many fruitless essays."

A young and inexperienced bee must also learn how to find her way home before starting out on her first serious foraging excursion. To this end she usually issues forth, often about mid-day, for a few preliminary or "play" flights, during which she studies the lie of the surrounding land, more especially the relative position of conspicuous objects to that of the hive. After each

such trial she widens somewhat the range of her investigation, exploring more and more of the territory, until at length she gets to know the country over a considerable area. Practical bee-keepers will tell you that in the end she can be trusted to find her way back safely after an outward journey of three miles; but exceptionally sagacious bees have returned unerringly to their hives from much greater distances.

Nevertheless, and despite the diversity of temperament and capability among individuals, the so-called "laws" of the hive are meticulously observed, save only in exceptional circumstances, or in crises threatening the existence of the community. The queen, although indispensable as the instrument of its continuance, is no ruling sovereign, but completely subservient to what has been termed "the hive-mind" as this is evidenced by the concerted action of the workers. A bevy of them follow her about, not only feeding and grooming her, but regulating her egg-laying by apportioning her food. As her age increases her fertility declines, and eventually—if in the meantime she does not migrate at the head of a swarm—the workers make plans to supersede her by starting to build royal cells. After supersedure the new and old queens may live amicably together for as long as the latter survives, the intense rivalry between these royal personages occurring only when two young princesses emerge at about the same time.

All such momentous decisions are arrived at and implemented by a sort of secret plebiscite of the workers—although how this is effected remains a baffling mystery. Basically, however, bee-behaviour is conditioned by atmospheric factors, especially temperature, since when this falls below 45°F. these insects are virtually paralysed and unable to fly or creep. With a rise in temperature above 60°F. activities in the hive increase, while at 85°F. the queen begins to lay; and when 95°F. is reached wax secretion and comb-building proceed apace, a constant stream of foragers issuing from and returning to the hive throughout the hours of daylight.

Within certain limits bees are able to regulate the temperature within the hive, the chief source of heat being the release of energy consequent upon their metabolism and that of the brood. But this central heating is insufficient to keep out the chills of winter, and when the outside temperature falls to about 57°F.

the bees form themselves into a closely packed cluster, and so remain throughout the long, cold months when all activity is perforce suspended. During this barren period food must be consumed, since hive-bees do not hibernate, but the individual ration is reduced to the barest minimum, the method employed being graphically described by Tickner Edwardes in the following passage. "The bees . . . nearest to the combs broach the full cells beneath them, and the honey is passed through the crowd, each bee getting her scanty dole. No one knows when a fresh supply may be available, although no chance will be lost to replenish the larder at the first sign of returning warmth. . . . Thus there is a system of slow browsing over the combs, until the dense flock of bees has reached the highest limit of the hive, when new grazing grounds must be taken. But the movement of the cluster is exceedingly slow —perhaps the slowest thing in the animal world. All recognize that existence depends on the stores being eked out to their utmost . . . so that the largest possible army of bee-nurses and foragers may be at hand in the springtime to raise the young bees that are to represent the future colony."

Some of the most remarkable advances in our knowledge of hive-bee behaviour are due to discoveries made experimentally by the Austrian scientist von Frisch, working with dishes of syrup placed at various distances from a glass-sided observation hive, and bees marked on their backs with coloured paints. Between the overlapping plates at the tip of the abdomen worker-bees have paired scent-producing glands which are extruded when their owner has been feasting on a rich store of food. Von Frisch found that if he covered the glands of these replete bees with shellac, the dish from which they had returned to the hive attracted far fewer visitors than a similarly placed dish at which the bees were not treated with shellac—the inference being that they had left behind them a characteristic odour which guided newcomers to the place where food was obtainable.

In the course of his investigations von Frisch also found that bees communicate with one another by means of what he has termed a "dance language". When a worker returns home after finding a specially bountiful supply of nectar or pollen she makes her good fortune known to the other inmates of the hive by dancing a sort of jig. Nearby workers are attracted by her antics,

show signs of excitement, and soon afterwards set out in search of the food whose existence has thus been indicated to them. Two distinct types of dance have been observed and described respectively as the "round dance" and the "waggle dance". If the location of the find is not more than fifty yards or so distant the round dance is performed by the home-comer as an indication that her sister bees should disperse and search round the hive for food having the same scent as that emitted by the dancer's body. The waggle dance, which takes the form of a very broad figure-of-eight, and during which the bee waggles her abdomen from side to side in a peculiar way, signifies that the food must be sought at a greater distance. Moreover, by her movements the dancer indicates to the bystanders not only the direction relative to the sun's position in which they must fly, but also tells them how far they must travel. That the bees do not depend for their impressions of what is happening upon sight is patent, because although both dances are occasionally performed in full view on the alighting board of the hive, they are usually enacted on a vertical comb in its dark interior.

All this sounds suspiciously like a fairy tale, but its truth is vouched for by eminent scientists whose conclusions were reached after long-continued observation and many carefully planned experiments which left no room for doubt that hive-bees are vested with subtle sensibilities of a kind quite different from those of the higher animals.

Hive-bees, on the whole, are remarkably free from internal parasites; but "foul brood", attributed to bacterial organisms (*Bacillus spp.*) and acarine disease due to the invasion of the tracheae or breathing tubes by a tiny mite are notable exceptions. Grubs infected by the former quickly die, putrefy and give off an evil odour. The mites, both in their larval and adult phases, feed by piercing the bee's tissues and sucking its nutrient fluids, thus sapping its vitality, besides suffocating it slowly by checking and eventually stopping their oxygen intake. Fungi and protozoa—microscopic animalcules—are also responsible for certain ills that afflict domesticated bees; but the so-called bee-louse—supposed to be a pigmy fly devoid of wings—is more of a sponger than a parasite, although its whole life is spent in hives. It infests all three castes of bees, but is found most frequently clinging to

the body of the queen, so that when swarming takes place it is carried by her to new quarters. Its eggs are laid on the comb, and and larvae burrow and feed in the wax capping of the cells. The adult does not suck blood, but when hungry creeps close to the mouth of its carrier, and apparently shares its food.

Much damage is sometimes done in hives by the caterpillars of certain moths, which in default of adequate protection may also be very destructive to stored wax. There are two species, the honeycomb-moth and the common honey-moth. The perfect insects are on the wing during the summer months and enter the hive at night to lay their eggs. The caterpillars feed chiefly on wax, forming long, silk-lined galleries through the comb and destroying many young bees by pressure. By preference they attack old combs where they can add protein to their diet by consuming pollen, while in all probability they are to a small extent carnivorous. They are gregarious, feeding in company, and eventually spinning clusters of dense, firm cocoons among the wreckage that they have caused. The green-shaded honey-moth, already mentioned as an intruder in the nests of wasps and humble-bees, occurs only rarely as a pest in bee-hives.

Wasps must be reckoned among the enemies of hive-bees, since when they are numerous in the late summer and autumn they are apt to essay honey-stealing raids ; but the door-keepers of a strong and irascible colony can usually be trusted to fend off the would-be invaders. The large death's-head hawk-moth is said sometimes to gain access to a hive, and to suck the honey out of the cells ; but here, again, the bees are usually successful in safeguarding their property. Foraging bees are exposed to the attacks of predacious insects, especially dragon-flies and robber-flies, while insectivorous birds, such as shrikes and titmice, also constitute a danger. In winter, the great tits have been seen to tap on the alighting board of a hive and to snap up the bees when they came out to investigate the cause of the vibration.

The appetite of toads for hive-bees is insatiable, and these amphibia are generally numerous in the vicinity of an old-established apiary. But, as Dr. Whitehead remarks, if the hives are supported on legs that the toad cannot climb, "such bees as he will snap up on the floor will be weak, dying or diseased, and by disposing of them he is doing the beekeeper a service."

Chapter Seven

ANTS

ANTS—*aliases* emmets and pismires—are in many ways the most highly specialized of all insects, alike in their physical structure and their instincts. None of them is conspicuous in point of size or coloration, but all are marvellously well able to further and protect their own interests. Very numerous in species, they are found all over the world from the equator to the fringe of the arctic circles. Except for a few which live parasitically as residents in the nests of other ants, they occur, like all social insects, in three castes—males, females and neuters or workers. As in the case of social bees and wasps the latter are imperfectly developed females, but they are always wingless and often differ in size and equipment among themselves, some exotic ants having evolved a type with disproportionately large heads and jaws which are known as “soldiers”, their sole duty consisting, it is said, in the protection of the community as a whole. In other instances the males and females also exhibit considerable diversity of form, some being wingless, others having wings—which, however, are invariably discarded immediately after the nuptial flight.

The so-called solitary- or velvet-ants, already referred to in Chapter Five, are more nearly related to the fossors or digger-wasps than to the true ants. They are found in most temperate and tropical regions, upwards of a thousand species having been described. In most instances their bodies are clothed more or less densely with a velvet-like pubescence in bands and patches of strongly contrasted and often vivid colours. Their most notable characteristic, however, is the extreme disparity of the sexes, the males being nearly always winged, the females wingless.

True ants often have a highly polished, metallic integument, but they are never brightly coloured. Moreover, they may be known by their sharply elbowed antennae and the fact that at least one of the segments constituting the “waist” joining the thorax to the abdomen is nodular in form. In some genera there are two of these knobby segments.

By contrast with that of most other insects the longevity of ants is astonishing. In captivity, workers have been known to survive for seven and queens for more than fifteen years. Unlike hive-bees they do not swarm, but constantly enlarge their habitations as the population increases. British ants build their nests subterraneously, often beneath mounds of earth or vegetable refuse, or in hollow trees and similar situations. They construct no combs of cells, but store their food and nurture their larvae in chambers of various sizes connected by passages ; but some ants—notably the jet ant—make extensive use of a kind of cardboard consisting of chewed fragments of wood and bark mixed with earth and cemented together with secretions from the salivary glands. When large, these “carton” nests, as they are called, have the appearance of a huge sponge, being made up of numerous irregular compartments separated from one another by thin walls that soon become covered with a delicate, bluish mould which is probably used as food by the ants. A fine example of one such nest is exhibited in the Insect Gallery of the British Museum (Natural History). It was built between the joists under the ground-floor boarding of a house.

The small black or garden ant is one of the commonest British species, of which there are some thirty-three. It ranges over the whole of Europe, and excavates its chambers and galleries in dry earth, frequently in wayside banks, but often under paving-stones or the hard surface of garden paths, the nests being built in stories one above the other when vertical space permits. The nearly related yellow ant is almost equally abundant, but prefers meadows and other grassy localities, and is seldom found in gardens. Its mounds—rather like elongated mole-hills overgrown with herbage—always have the long axis pointing eastward, and in the Alps are said to serve as compasses to pedestrians who have lost their way in fog or darkness. The benefit derived by the ants from this orientation appears to be that the eastward end of the mound, which alone is inhabited, keeps warmer and drier than it would if it faced in any other direction.

Both these little ants are very partial to the honey-dew discharged by aphides and scale-insects, and keep herds of the former under supervision, sometimes erecting slight earthen shelters over those that they do not carry into their nests as a

protection from the weather and enemies likely to harm them. Some species of ants actually cherish the eggs of these protégés during the winter, bringing them out into the open again and placing them on suitable plants when the mild days of spring return. The little yellow ant relies for almost all its food on the sugary excretions of the aphides that live on the roots which penetrate into its excavations ; while the Swedish entomologist Okland estimated that the amount of honey-dew collected by a large colony of the wood-ant during the summer months must be equivalent to 20 lb. weight of dry sugar.

Ants rear their young chiefly on a kind of pap regurgitated by the workers, and this is also frequently given to the egg-laying queen. In addition, a small quantity of solid food—bits of insects, etc., brought in from the chase—is placed within reach of the older larvae. But the adults, especially those of the larger species, feed on a great variety of substances, both animal and vegetable, and in general may be said to play a beneficial part in the economy of nature, for they act as scavengers by clearing up carrion and organic refuse of many kinds, and undoubtedly destroy large numbers of caterpillars and other injurious insects each season. Of the latter, Donisthorpe calculated that in favourable weather the daily average carried home by a prosperous community of wood-ants cannot fall far short of 100,000.

The importance of the wood-ant in the biological control of forestry pests was long ago recognized in Germany, and in 1880 a law was enacted whereby a person collecting its cocoons or wantonly disturbing its nests was liable on conviction to a fine of one hundred marks or a month's imprisonment ; and efforts have since been made by mass breeding and distribution of fecund female ants to increase the numbers and spread of this species in woodland areas. In China, the use of ants to destroy pests was practised at least as early as the thirteenth century, reference being made in the literature of that period to a special class of labourers called "ant-gatherers" ; and at the beginning of the present century ants were being systematically collected by the hill men for sale to dwellers in the plains who used them to protect their orange trees from caterpillars. More recently the attempts made in Ceylon to employ species of spinning-ants as a check to the

ravages of the coffee-bug had to be abandoned because these irascible insects attacked the native workers so fiercely that they threatened to leave the estates.

Owing to their habit of fostering aphides ants help materially in the perpetuation and dispersal of these nuisances, and for this reason are execrated by gardeners. Besides this they occasionally injure seedlings, and very often almost bury low-growing plants under the heaps of earth brought up from their subterranean excavations. They are apt also to enter houses, making their way into larders and store-cupboards, where they may be most easily trapped in pieces of old sponge saturated with syrup, and destroyed by dropping these periodically into boiling water. Nests, when located, may also be drenched with boiling water ; but a surer way to get rid of them is to make a hole in the centre of each to a depth of about eight or ten inches and then pour in from one to two ounces of bisulphide of carbon—remembering always that the vapour given off by this chemical is highly inflammable, as well as poisonous if inhaled.

In Britain, the so-called Pharaoh's ant is the most mischievous species. It is an alien, whose country of origin is unknown ; but its craving for warmth and shelter, and its inability to tolerate an open-air life in our climate, suggest that it belongs to the tropics. Individually it is very tiny, some seventeen thousand of the workers weighing only one gramme ; but when established under favourable conditions in a factory or warehouse it increases with great rapidity and may prove very destructive to sugar, ground almonds, spices and other condiments. Tradition credits it with one dietetic virtue, namely, that its marauding gangs will mob and massacre bed-bugs when they get the chance, and are capable of ridding premises of these objectionable creatures in a short time if they are left to their own devices.

The Argentine ant is another troublesome little species which is carried about by shipping, and when once established in a locality soon becomes a serious pest. Happily, it has not, up to the present, gained a footing in the British Islands, although its presence has been reported from two or three widely separated places.

With us, the most conspicuous nests are made by the common red wood-ant or horse-ant—our largest native species,

the head to tail length of its worker caste varying from 4 to nearly 10 mm. They will be found in woodlands, especially under pine trees, and consist of a mound from three to four feet in height and ten or twelve yards in circumference, formed of pine-needles, small twigs and other fragments heaped above a labyrinth of galleries and chambers extending far into the ground below. They are often laid open and dispersed by gamekeepers so that the pheasants may get at the pupae in their cocoons which, under the title of "ants' eggs", are also collected and sold for feeding cage-birds and fishes in aquaria. Left undisturbed these mounds and the subterranean workings which they cover persist for many years, and eventually house a population which may number 100,000 or more individuals, including in all likelihood several egg-laying females, or queens; but winged males and princesses are only found in them as the pairing season approaches.

The meadow-ant is less common than the red-ant but very like it in many ways and has similar habits. It is, however, much darker in colour, while its hillocks—which never exceed a foot in height and two or three feet in circumference—are more likely to be found in open spaces than in woods, and are usually composed of much coarser materials. Moreover, the workers are less fierce and do not spray formic acid about so freely when their community is molested.

The blood-red ant—our only slave-making species—also resembles, and is nearly as large as, the red-ant, but its nests are entirely below the surface, with no mounds raised above them.

On a fine, warm day in summer, often during July or August, the brood of winged males and princesses issue from their nest and after a little wandering, apparently aimless, rise in the air on what is known as the marriage flight—many to be chased and devoured by insectivorous birds, such as swallows and martins, while others which come safely to earth are snapped up by toads, lizards and so forth. In some instances mating occurs in the air, but it may be postponed until the partners reach the ground. After it has taken place the male soon dies, but the fertilized female discards her wings, either by rubbing them against the stems of grasses and other plants, or by pulling at them with her jaws. Instinct then impels her to seek shelter in some hole or cranny

where, after closing the entrance, she remains fasting, perhaps for several months on end, meanwhile laying her eggs and feeding the larvae when they hatch on the secretions of her salivary glands. During this period of seclusion she draws upon reserves of nourishment in her own body to keep herself and her young alive, the decomposition of the now useless wing-muscles augmenting the available supply. But she has been observed also to eat some of her own eggs. Eventually, when adult workers emerge from the first-formed pupae, they break their way out of the brood-chamber and sally forth to collect food. Later, they commence building operations ; and in this way a new community is brought into being.

This is the normal procedure ; but some species of ants seem to have lost the ability to found fresh settlements on their own account. The fertilized queens of the wood-ant, for instance, either (1) return to the nest in which they were bred, or (2) ally themselves with a neighbouring community, or (3) enter the nest of another—usually a related—species. In the last event the workers of the invaded colony may chivy the intruding queen and drive her off, if they do not succeed in killing her ; or she may manage to ingratiate herself with them and be allowed to live side by side with the rightful queen, so that the community becomes mixed, and curious complications result which may end in its extinction. The more usual way, however, in which the wood-ant forms fresh colonies is for a superfluous queen with a following of workers to emigrate and found a new nest not far from the old one—a kind of incipient swarming !

The dark guest-ant, of which the worker caste no longer exists, foists itself off on the turf-ant, in whose nests its males and females live and breed. Here they are not merely tolerated, but petted by the rightful owners. They are groomed, carried about and fed by these dupes, being unable even to eat without assistance. The male, in particular, is a curiously decrepit object, looking like a cripple and walking with difficulty.

Exactly how this strange intimacy comes to pass is at present uncertain, but it seems probable that a gravid female of the “cuckoo” species manages somehow to enter the nest and so ingratiate herself with the worker population that they depose and kill the reigning queen in favour of the alien ; for according to

Donisthorpe, she is hardly strong enough to do the killing herself. But there is no doubt that before long she is firmly established as queen-mother of the stolen kingdom. Yet her triumph is short-lived; for when the workers of the invaded nest die—which they probably do in the course of a year or so—her reign and her life end. But in the meantime pairing has taken place between the brothers and sisters of her progeny, and the latter disperse to find other turf-ants' nests, there to carry on the disreputable tactics of their species.

Some of the smaller ants build no nests of their own but live as lodgers in those of larger species. An example is the shining guest-ant, which is found only in the nests of the red-ant and its near relative the meadow-ant. Apart from the fact that it thus obtains shelter and warmth, as well as safety from its enemies, its relations with its hosts are somewhat obscure; but it is supposed to subsist on unconsidered trifles. It moves freely about in the nest and is usually treated with indifference, although occasionally menaced with open jaws—but never actually attacked—by the owners. When the latter migrate, their unbidden guests follow, carrying their brood to the new quarters.

The little robber-ant, a rarity in Britain, but common in North and Central Europe, lives in the walls of other ants' nests—especially those of the long-suffering negro-ant—much as mice live behind the wainscoting of our houses, and raids its hosts' nurseries, carrying off the helpless grubs for food. The negro-ants cannot evict it because they are too large to enter its runs and chambers. "It is as if (wrote Lord Avebury) we had small dwarfs . . . harbouring in the walls of our houses, and every now and then carrying off some of our children into their horrid dens."

This social parasitism, as it is called—one kind of ant victimizing another—reaches its climax among certain tropical species, of which the North African executioner-ant is a conspicuous example. After her nuptial flight, the pregnant female alights near the nest of the Nigerian ant, into which she is dragged sooner or later by some of its foraging workers. Once inside, she seeks out the queen-mother of the community—considerably larger than herself—and mounting on the back of this royal personage spends several days in deliberately biting off her head. One must suppose that while thus engaged she acquires the characteristic

aura of the nest ; for as soon as the decapitation is complete, the workers—by whom she has hitherto been treated with scant courtesy—readily adopt her as their new queen, and start to rear her brood.

This exhibition of savagery has its parallel in the New World where several tiny queens of an Argentine ant simultaneously invade a nest of the local fire-ant, climb upon the back of the rightful queen, and co-operate in gnawing off her head, thus terminating her reign and establishing themselves as her successors.

The blood-red robber-ant has already been referred to as our only slave-keeping species ; but it is not greatly dependent on the practice. It occasionally makes raids on the nests of smaller species—usually those of the long-suffering negro-ant, which has been described as shy and cowardly, inclined to flight rather than fight. From these incursions a supply of larvae and pupae are carried off and carefully tended by their captors. The adults, on their appearance, make no attempt to escape but take part in the activities of their owners' nest as if it were their own ; and when, as sometimes happens, the masters change their quarters, the slaves trek—or are carried—to the new establishment. The European Amazon-ant would probably have become extinct long ago but for the assiduity of its slaves, by which it is carried about from place to place, and periodically fed—being either unable or unwilling to fend for itself or its young, even when surrounded by food. Being fierce and warlike in disposition it is never at a loss to secure as much forced labour as its needs require.

In their growth and development ants undergo a very complete metamorphosis, strongly contrasted larval and pupal stages always intervening between the egg and the imago or perfect insect. The duration of the individual life-cycle varies among the different species from a few weeks to many months, or even to over three years ; but that of the pupal stage is relatively short, seldom exceeding two or three weeks. The white or yellowish eggs are small in proportion to the size of the adults, and may be either round, elliptical or elongate in form. The blind and legless larvae or grubs—also white or yellowish in tint—are more or less banana-like in shape with the short neck curved somewhat downward and the hinder end of the body broadened. The pupae

of some ants are naked, others are enclosed in an ovate cocoon spun by the full-fed larva, from which the perfect insect is often—though not invariably—assisted in extricating itself by its nurses, the workers, by whom, moreover, the delicate pupal skin is usually licked off.

Although ants frequently eat their own eggs—possibly as a precaution against over-population of the community—they excel all other animals in their devotion to the rising generation. The larvae are not nurtured in separate cells but piled up in nursery chambers, classified according to age, and constantly carried about from one part of the nest to another with never failing solicitude for their welfare. It has been pointed out that whereas the larvae of the more primitive groups of ants always spin cocoons before pupating, the pupae of the more highly developed forms are “naked”, almost without exception. But in some instances where no cocoons are made the ability to produce silk is retained by the larvae and diverted by the workers to another use, namely, for joining leaves together to make nests. These curious dwelling-places were first noticed by Captain Cook during his voyage in the *Endeavour* (1768–71), built in branches of mangroves in Northern Queensland. The foundress female or queen of this particular spinning-ant, which is also found in tropical Asia and Africa and is green in colour as befits her tree-dwelling habit, first raises a small brood in a curled-up leaf under cover of her body, much as a hen protects her chicks. As soon as a sufficiency of workers is available they commence building operations by drawing the edges of two leaves together until they meet. Meanwhile, others seize hold of the larger larvae and—gently squeezing them—apply their mouths to those parts of the leaf-edges where joints are required, moving them from side to side in a manner suggestive of sewing, so that a close webbing of silk results. This process is repeated over and over again until at length the nest, when completed, measures a foot or more in diameter.

In tropical and sub-tropical countries many species of ants inhabit the hollow stems and other natural cavities of plants. This was first observed by Thomas Belt, who in the course of his travels in Nicaragua noticed that the twin thorns of the bull's-horn acacias growing in this region are nearly always tenanted by

ants, which "make a small hole for their entrance and exit near one of the tips and also burrow through the partition that separates the two thorns, so that one entrance serves for both". When young, the thorns are filled with a sweetish pith, which the ants eat out. Then, when the outer skin or cuticle hardens, they use the interior as a combined storehouse and nursery. Further investigation by Belt showed that this acacia-thorn ant protects the trees in which its homes are made from the attacks of other insects, more especially the leaf-cutting ants, concerning whose activities more will be said on a later page. If a leaf is touched or a branch shaken the defenders swarm out from their retreats in thousands, ready to attack with jaws and stings, and usually succeed in routing the marauders. It is an interesting fact that the acacia furnishes its guardians with an abundance of food as well as safe lodgings. Crater-like glands at the base of its petioles or leaf-stalks secrete a sugary substance not unlike honey-dew, while many of the leaflets bear small "pseudo-fruits", rich in albumen, at their tips; and these two comestibles seem to constitute the entire diet of the ants.

Since Belt wrote, many additional instances have been recorded of ants living habitually in spaces which occur, or which they themselves have scooped out, in the structure of various plants—as, for example, the hollow resting-stems or "pseudobulbs" of the Honduras cow-horn orchid. At the base of these there is always a small opening that admits ants to the interior, which they convert into a regular formicarium, or ant-city, and fiercely defend against would-be intruders.

Some epiphytic orchids that grow high up on the branches of trees in the dripping forests of Guiana form dense masses of fibrous roots among which ants make their homes, filling unwanted gaps with particles of soil carried up from the ground, and thus placing a welcome supply of mineral salts at the disposal of the host-plants. They are also said to protect them from attack by cockroaches and other pests. Certain East Indian epiphytes are notable for the tumour-like swellings at the bases of their main stems. These are riddled internally by a labyrinth of passages and chambers invariably inhabited by ants; but whether the interstitial structure is produced normally by the plants, or is the result of excavations by the ants, is uncertain.

Even more extraordinary is the symbiotic or mutually beneficial relationship which exists between ants and certain very curious East Indian epiphytes of the genus *Dischidia*. These produce pitcher-shaped leaves, one inside another, similar in design to a double-saucepan. The inner pitcher—like those of the more usual pitcher-plants—appear to serve solely for catching insects and other small fry which it subsequently digests and assimilates. But the function of the outer pitcher is quite different. Its inner walls distil water and a sweet substance very similar to grape-sugar in chemical composition. The latter attracts ants and induces them to start house-keeping ; to which end they carry up soil from the ground for building purposes, so that eventually the space between the two pitchers is converted into a sort of flower-pot, filled with moist earth, into which the plant sends a special root system to absorb water and chemical nutriment for its own use. It looks as if the plant had bribed the ants to make their homes in its pitchers and by so doing has been amply rewarded !

In the course of their long history ants have evolved some novel and interesting ways of conserving and augmenting their supply of food. In this respect the honey-ants of Mexico and the southwestern United States are especially noteworthy, a percentage of their workers—known as “repletes”—being adapted to serve the community as reservoirs. The nests are subterranean, and the foragers issue at night to collect sugary exudations, chiefly from certain oak-galls, but also from aphides and scale-insects. On their return, they make over their spoils to the repletes, which pass most of their time hanging motionless from the roof of little chambers reserved exclusively for their accommodation. They receive the sweet liquid into their crops, which eventually become so swollen that all the other organs are forced against the walls of the abdomen, stretching them to such an extent that the insects are converted into globular honey-pots. When thus fully charged they can hardly move, and if they chance to let go their hold upon the ceiling they are unable to regain it without assistance. When any of the ordinary workers solicit them for food they disgorge some of their hoard ; and thanks to these living store-tanks the community is able to tide over long periods of drought and scarcity. In the average nest there may be from two to three

hundred repletes, and in the countries where these strange sweetmeats are available they are much in demand by the natives. Not unlike small, amber-coloured sultanas in size and shape, they can be bought by the gallon in Mexican markets. All that the buyer need do to convert them into mead is to pound them in a mortar, afterwards straining off the fluid through muslin and setting it aside to ferment.

Many species of ants collect seeds and carry them to their nests for food, particularly the kinds—such as those of the dog-violet and the gorse—which have at one end a fleshy outgrowth, or caruncle, rich in oil. This fact has been familiar to mankind from remote antiquity and is twice referred to in the Book of Proverbs. The ants called harvesters occur in many parts of the world, with their headquarters round the Mediterranean basin and in Texas. The former, some species of which were studied by J. T. Moggridge in southern Italy, systematically garner the seeds of speedwell, fumitory and other plants as well as oat grains. Most were gathered from the ground, but some ants—presumably more enterprising than their fellows—were seen to climb up stems and deliberately detach seeds, which they either carried down or dropped to the earth, to be retrieved later. The seeds are stored in special chambers, of which each community has about a hundred on the average, with a total capacity of twenty ounces or more. The ants prevent them from sprouting until they are needed for food—probably by keeping them cool and perfectly dry; but when rations are required germination is encouraged, so that the starch content is converted into sugar—the staple of the ants' diet. When this stage is reached, further growth is arrested by nipping off the young shoots.

In recounting his observations of the harvesting ants of Texas H. C. McCook suggested that these insects practise a primitive kind of agriculture by clearing away all the vegetation in the vicinity of their nests except two species of grass—known locally as “ant-rice”—by whose seeds they set great store; but this has not been substantiated by more recent investigators. The clearance which the ants undoubtedly make round the site of the nest appears to serve chiefly as a drying ground for their harvest before it is garnered. Any seeds which have sprouted too much to be of use for food are dumped at the periphery of this area, where

many take root and grow, so that a near-at-hand crop of the favourite grasses is actually produced. But in all likelihood this is a purely accidental occurrence, unconnected with any provenance on the part of the ants.

Leaf-cutting ants of many species occur throughout America from Texas to Patagonia, the largest and most specialized types being the saübas, members of the tropical genus *Atta*, for the first detailed account of whose habits we are indebted to H. W. Bates. They dwell in extensive subterranean nests, above which the excavated earth is piled in a mound that may be several feet high and thirty or forty feet in diameter. From these the workers issue in gangs, and Bates's graphic account of their methods is worth quoting. "Each one (he writes) places itself on the surface of a leaf, and cuts with its sharp scissor-like jaws a nearly semi-circular incision on the upper side; it then takes the edge in its jaws, and by a sharp jerk detaches the piece. Sometimes they let the leaf drop to the ground, where a little heap accumulates, until carried off by another relay of workers; but, generally, each marches off with the piece it has operated upon, and as all take the same road to the colony, the path they follow becomes in a short time smooth and bare, like the impression of a cart-wheel through the herbage." Along these roads the ants stream to and fro, and their energy and numbers are such that they are capable of stripping a large tree of its leaves in a few hours.

The use which these saüba ants make of the enormous bulk of material which they accumulate in their habitations was for long a matter of speculation; but Thomas Belt discovered that the original pieces of leaf were cut into tiny fragments and piled up in sponge-like masses within the larger chambers of the nest, and that these masses became clothed with a minute white mould or fungus on which the insects appeared to feed. It remained for the German naturalist Fritz Müller to establish beyond doubt the fact that these ants actually cultivate a peculiar kind of fungus producing myriads of tiny nodules which constitute the sole food of the insects and their brood. Furthermore, he demonstrated by experiment that these miniature mushrooms, as they may fairly be called, are produced only when the fungus is tended by the ants.

That the mushroom-beds are systematically manured with the liquid faeces of their makers is an interesting detail established

ater. The young, prospective queen, when she sets forth on her nuptial flight, carries in a little pouch beneath the mouth a tiny pellet of the authentic fungus to be used for starting fresh cultures when a new nest is founded. As so often happens among ants, the workers in an established community vary much in size and development. The largest, with big heads and scimitar-like jaws, stand guard at the entrance to the nest; those of medium size, which are more numerous, go abroad to cut and bring back the leaf-fragments; while the smallest stay at home to look after the mushroom-beds and nurse the young. The newly hatched larvae are nourished on pap regurgitated by the workers, but the older ones fend for themselves by feeding on the fungus nodules by which they are plentifully surrounded.

The predatory wandering or foraging-ants of the New World tropics and the driver-ants of tropical Africa are of special interest because, although gregarious and highly socialized, they make no nests but live a nomadic life. Some species are also remarkable for the extraordinary diversity in size and physical equipment of the worker caste, some of the largest—the “soldiers”—having disproportionately huge heads and immensely long, sickle-shaped mandibles, useless for any purpose save fighting. Although they are often blind, or at best very deficient in sight, the habit of foraging-ants is to travel about in enormous numbers, often marching in broad columns with military-like precision, killing and devouring all the insects—and even small reptiles and mammals—that they may encounter. They occasionally enter houses, clearing them of the cockroaches and other pests by which they are infested. From time to time, for the purpose of breeding, they either utilize the nests of other ants with settled habits—forcefully evicting the rightful owners—or else go temporarily into residence in hollow trees or under fallen trunks. Here they hang in a dense cluster, like a swarm of bees, with the queen and brood in the centre, out of harm’s way. “I was surprised to see (wrote Thomas Belt, who first described this strange practice) in this living nest tubular passages leading down to the centre of the mass, kept open, just as if it had been formed of inorganic materials. Down these holes the ants who were bringing in booty passed with their prey. I thrust a long stick down to the centre of the cluster and brought out clinging to it many ants holding

larvae and pupae." Truly an astonishing method of fostering the rising generation !

The African driver-ants have similar habits and are even more formidable when on the march. They attack and destroy large snakes, as well as the birds and beasts that fail to get out of their way. The males are large winged insects, measuring as much as an inch and a quarter from head to tail, while the females—of which only a very few examples have so far been found—may be twice as long, and when gravid far more bulky, their cylindrical abdomens being then greatly distended with eggs. These ants with no permanent abode and living exclusively by hunting soon exhaust the food supply of a district, and must needs move on ; and when this happens while breeding is in progress the whole colony, carrying the brood with it, treks to another site. Strangely enough, these formidable ants are pestered on these occasions by certain flies, about the size of bluebottles, which hover over the columns and when favourable opportunities offer swoop down and snatch the larvae or pupae from the very jaws of the workers, carrying these innocents away to a safe distance, there to suck their juices.

The bull-dog ants of Australia, although primitive in type, are said to be the fiercest of their kind, but are less dreaded than the foragers and drivers since they do not hunt in packs. The workers of some species exceed an inch in length and are armed with poisonous stings with which they can inflict painful and even dangerous wounds. Some are renowned for their jumping powers, being capable of covering a foot or more in one leap. The females, after shedding their wings, differ little in appearance from the workers, but the males are much smaller, with poorly developed mandibles and straight—instead of whip-like—antennae. In many instances the nests, like those of our native wood-ant, are hillocks of vegetable debris piled above a complex system of subterranean workings ; but some species constitute themselves the bodyguard of favourite shrubs, which they defend against hostile attack, just as the Nicaraguan ants defend their cherished acacias.

In modern times the ways of the ant have been considered by a succession of competent observers from the younger Huber onward for fully a century and a half, yet so far no facts have come

to light as sensational as those vouched for by von Frische in respect of the hive-bee. All ants are adequately endowed with the senses of touch, smell and taste. Many have eyes, although these are very small in some species, while others are completely blind, and the latter naturally rely chiefly on the acuity of their touch when investigating their surroundings. Tactile hairs and similar structures are present all over the body, but are especially numerous and varied on the antennae, which are used by ants not only for examining objects, but also to communicate with each other. Eric Wasmann has enumerated a number of distinct antennal strokes—quick or slow, heavy or light, and so forth—that he believes are used to transmit definite ideas. Nobody who has watched ants, even for a short time, can have failed to notice that if one finds something worth conveying to the nest but too heavy to be moved without assistance it hurries home and returns with a band of helpers. Again, the rapidity with which ants rally to the defence of their communities when these are attacked proves their readiness to circulate information when the need arises.

Olfactory end-organs are also situated in the antennae in close association with those of touch. Indeed, Wasman called the antennae “touching-noses”, since by their use ants not only exchange items of news, but recognize nest-mates by their characteristic aura or scent. The forgathering of friends gives evident satisfaction, and frequently one will solicit and receive food from the other; but when strangers or enemies meet they immediately threaten each other with open jaws. Many ants likewise depend largely on their sense of smell when tracking down food and for finding their way about, though others, with well-developed eyes, rely to some extent on sight. But the latter, at best, are myopic. Donisthorpe frequently observed a worker wood-ant, when pursuing a small beetle, lose sight of it and run blindly past its intended prey. Yet Lord Avebury showed that ants perceive and avoid the ultra-violet rays of the spectrum, and Auguste Forel proved that they did this through the eyes—by coating these organs with opaque varnish.

Some arboreal ants are said to tap with their heads on leaves, and when many do this simultaneously an audible drumming sound is produced which is believed to serve as an alert or danger

signal. Most species are equipped with a stridulating or rasp-and-file apparatus at the base of the abdomen, also with ear-like organs—similar to those of crickets and long-horn grasshoppers—either in the tibiae or some other part of the body. These structures indicate that their owners are capable of producing and detecting sounds. But Lord Avebury, notwithstanding repeated tests, failed to obtain the smallest evidence that his ants perceived any of the noises that his utmost ingenuity could devise, and therefore concluded that their auditory capacity was entirely outside the range of human hearing. Recent investigations indicate that ants may be more sensitive to the vibrations of solids than to those of air; but some observers maintain that they perceive aerial vibrations to a lesser extent.

Summarizing the pros and cons of ant psychology, Donisthorpe concludes that these insects “possess senses similar to our own in effect, though not in degree, and in many of their actions they are influenced by education, experience and memory”.

Except at the time of the marriage flights the only serious vertebrate enemies of ants in this country are the woodpeckers—more especially the “yaffle” or green woodpecker—which in winter make holes in the defences of the nests and gorge themselves with the larvae, pupae and workers. In this they are greatly helped by their exceptionally long tongues, which can be protruded far beyond the tip of the bill, and are kept moist by a sticky secretion from large salivary glands. Similar, but more worm-like, adhesive tongues are characteristic of the ant-eaters of southern and central America and the pangolins of the Old World tropics. The great ant-eater—surely unexcelled for strangeness among mammals!—roams abroad at night in search of ant-hills and termite-mounds which it rips open with the claws of its powerful hind limbs in order to lick up the inmates. The unrelated but scarcely less bizarre aard-varks or ant-bears of Africa—looking like ungainly kangaroos with narrow heads, pig-like snouts and donkey’s ears—also feed chiefly on these insects and are similarly equipped with strong digging claws and extensile tongues. Then there are the echidnas or spiny ant-eaters of Australia and New Guinea, the ant-thrushes and ant-pipas of South America, to say nothing of a host of other beasts, birds, reptiles and amphibia

whose food consists largely, if not exclusively, of ants and their brood. The armies of foraging and driver ants are invariably accompanied by flights of insectivorous birds eager to pounce upon stragglers from the advancing columns.

Ants' nests, especially those of the larger species, harbour many intruders. Donisthorpe catalogued more than 250 myrmecophiles, as such interlopers are termed, found by him in the nests of British ants, while Wasmann, whose investigations covered a wider field, listed nearly 1,200. The majority are insects of one sort or another, but a fair number of spiders, mites, crustacea and other small arthropods go to swell the total. Many are scavengers or sneak-thieves which escape molestation and possible destruction by the ants because of their unobtrusiveness or their agility in taking cover if pursued. Others are protected by the extreme hardness of their armour, or—skunk-like—by a repellent odour. Not a few, however, are treated as honoured guests by the rightful inhabitants of the nest, having developed special glands that excrete sweet or aromatic substances of which the ants are very fond. These last are the arch villains of the piece, for they requite the hospitality of their hosts by practising a peculiarly dastardly form of parasitism.

The most highly specialized of the favoured residents are certain beetles, some of whose life-histories have been fully worked out. One is a tiny blind and wingless species (*Claviger testaceus*) very ant-like in guise, which may usually be found in colonies of the small black and yellow ants—especially those of the latter. Its excretory glands, hidden among tufts of hairs on its back, emit a sweetish fluid that gathers in minute pearl-like drops which the ants lick off with evident gusto. They take the greatest care of these beetles, feeding and cleaning them with as much punctiliousness as if they were dealing with their own offspring, and when the nest is disturbed hurriedly carry them to the safety of its deepest workings, whence they are brought up again when the danger has passed. There can be little doubt that but for this fostering and protection on the part of its patrons this beetle would long ago have become extinct, for it seems to have lost all capacity to fend for itself, and is never found outside ants' nests. Does it evince gratitude? On the contrary, it sows its eggs among the ants' brood on which its own grubs prey, although their ravages are

not usually sufficiently serious to bring about the downfall of the colony.

The same cannot be said of the ants'-nest beetle (*Lomechusa strumosa*) that foists itself off upon communities of the blood-red or slave-making ant, by whose workers both it and its young are cherished, just as if they were authentic members of the community. The upshot of this misplaced hospitality is disastrous, for the unbidden guests are voraciously predatory. Although constantly fed by the ants they help themselves to their hosts' eggs, larvae and pupae, while their own fat, white larvae do the same. As a result of this sapping process the ant population steadily dwindles until a point is reached when the community can no longer maintain itself in being; and when this happens the progeny of the aggressors betake themselves to other colonies, which are in turn bamboozled and slowly destroyed.

The survival as a species of this barefaced sponger appears paradoxically to hinge upon occasional oversights on the part of the ants, whose larvae spin cocoons before changing to pupae. When the time comes for them to do this they are covered with soil by the nurses, or buried in shallow holes, to provide them with points of attachment for their silken threads. Afterwards, when the cocoons are complete, they are disinterred, carefully cleaned, and piled in heaps. The beetles' larvae are treated in exactly the same way; but since they make no cocoons most of the pupae are fatally injured by the cleaning process, and these are carried out of the nest and thrown on the rubbish heap. The race is perpetuated by the few that escape the ants' notice.

Strangely enough, the caterpillars of many blue butterflies, including all our indigenous species, develop "honey-glands" on the dorsal surface of the seventh abdominal segment which render them attractive to ants. The workers of one of our native varieties actually carry those of the large blue into their nest, where they prey upon the young grubs and eventually pupate. The following spring the adult butterfly emerges, makes its way into the open air, and immediately climbs up the stem of some plant to which it clings until its wings have expanded and hardened sufficiently for flight.

A number of insects habitually make use of the hillocks built by ants as breeding places. The gregarious caterpillars of the

Any wood-ant moth—a near relative of that household nuisance, the webbing-clothes-moth—spin their silken tunnels among the accumulated vegetable refuse, on the choicer portions of which they feed. The large grubs of the metallic green rose-beetles are also found frequently in these mounds, to which the females resort for egg-laying.

Among the many insects and other small creatures associated with ants in the capacity of scavengers the disc-shaped larvae of a two-winged fly call for special mention. They have been found in the nests of several British species, where they dispose of excrement and other organic refuse, and are so flattened that the ants run easily to and fro over their backs, apparently quite unaware of their presence.

The rising generation of the four-spotted clythra beetle live in the nests of the wood-ant, into which the adult female—not unlike an extra large, elongated ladybird in appearance—gets her eggs conveyed by a diverting piece of instinctive trickery. She makes them up into little packets that look like bits of twig and drops them to the ground from the overhanging branches where she spends most of her time. The ants, always on the look-out for odds and ends of building material, sooner or later find and carry them home to their nest, in which the larvae subsequently take up their quarters. Like caddis-worms, they construct and live in cases which they decorate externally with fibrous fragments and drag about with them, the head and legs protruding from the narrower end. They are scavengers with vegetarian proclivities and help to keep the galleries and chambers of the nest clean and unobstructed. So long as they retain their disguise the ants leave them alone, but when the perfect beetles appear they are attacked and chivied out of the nest.

As for sneak-thieves: the French entomologist C. Janet has an amusing account of the audacious way in which a little wingless insect related to the silver-fish of our larders and store-cupboards steals food from the very mouths of the ants whose nests it frequents. Ants are not greedy, but frequently feed one another. Foragers returning home with their crops filled with nectar or other juices are often solicited for food by their fellows that have not left the nest. When this happens the two stand face to face and a drop of liquid is passed from one to the

other. It is while two ants are thus engaged that the theft is perpetrated. It need hardly be said that these rogues are constantly chased by the ants and if caught summarily dealt with ; but as often as not they save themselves by darting into crevices inaccessible to their pursuers.

Some observers believe that certain flies and other insects not resident in the nests have evolved a technique for inducing ants in the open to give them a meal, thereby obtaining a share of the food being carried to the community ; but this needs additional confirmation.

In those countries where they occur ant-lions must destroy large numbers of foraging ants. They are the larval forms of certain insects with a superficial resemblance to dragon-flies, and are represented in most tropical and temperate regions, ranging into southern Sweden, but, rather surprisingly, not found in Britain. Some lurk in crevices and hunt in the open ; others make conical pits and thus entrap their victims. This is the method adopted by the common European species whose habits were first described by Réaumur, who also pointed out the inaptness of applying the name "lion" to a creature which makes its captures by strategy rather than by strength and rapidity of movement.

When constructing the pitfall for which it is famous the ant-lion ploughs round backwards in diminishing circles, constantly jerking out the loosened soil with its shovel-like head. The final result is a funnel-shaped hollow, in the bottom of which the maker lies buried with only its formidable jaws exposed. An ant—or any other small insect—that chances to run over the edge of the pit slides downward on the yielding particles of sand, its descent being hastened by the ant-lion, which throws up more sand upon the struggling prey.

Ants are more aggressive than any other insects, and in sheer pugnacity probably excel all the rest of the animal kingdom. Those of one colony usually exhibit marked hostility to ants of another colony, even when of the same species, although they readily recognize and show friendliness to members of their own, even after lengthy periods of separation. Some species habitually raid neighbouring communities to pillage their stores of food, or—as we have seen—to collect slave labour. The poison sacs of those that lack stings serve as reservoirs whence venom—usually

Formic acid, which has a toxic and corrosive action—is squirted from an aperture at the tip of the abdomen. A stingless ant may bite an enemy with its jaws, then spray poison into the wound. When a nest is attacked and its outworks partly demolished the ants hurry to points of vantage and eject their formic acid into the air. This collective action often serves to disconcert and drive away the foe, so that fighting at close quarters is avoided. All the same, ants are capable of waging the fiercest warfare, cutting one another in pieces with ruthless ferocity.

Despite their prowess as warriors ants do not always score a victory. When in tropical countries their armies meet foraging parties of their unrelated namesakes, the white-ants or termites, they sometimes experience an unexpected and extremely unpleasant reverse. For the gangs of blind termite workers are escorted by a bodyguard of soldiers whose method of attack is to squirt a glutinous fluid in the faces of their opponents. For a time the casualties try by rubbing their heads against stones and debris to rid themselves of the viscous substance, but without avail; and in the end this loathsome form of attack invariably proves fatal.

Ants resemble bees rather than wasps in their mode of overpassing the winter. Even in temperate or cold regions they do not die off at the approach of autumn, but go deep into the ground, sometimes three or more feet below the surface, and there huddle closely together as if for warmth. During this period of hibernation they remain completely inactive and as far as is known do no feeding. From late October until the following spring the hillocks of the wood-ant seem lifeless and deserted. But this species is hardy and one of the earliest afield. On fine days in February, if the season be a mild one, the workers may be seen massed in the sun on the top of their nest, and a little later foraging and building operations are resumed in earnest. March 22 was the earliest date on which the reappearance of the black ant was noticed by Gilbert White of Selborne.

Chapter Eight

TERMITES OR WHITE ANTS

THAT the social way of life should have evolved independently in two groups of insects so widely separated as the ants and the termites is very remarkable. The term "white ants", as applied to the latter, is a regrettable misnomer, since they are not white, while in structure and manner of growth they are totally distinct from ants properly so called. They have been described as "socialized cockroaches", but this is to stretch a point of similarity unduly. Actually, they resemble more closely the tiny book-louse, which is common in old houses and often makes itself a nuisance in neglected libraries by gnawing the pages of books—whence its popular name. Well over two thousand species of termites are known to exist, but although a few occur in the Mediterranean region and some fifty-five in the United States, the group is essentially tropical in distribution. No representatives are found in Britain or northern Europe.

The co-operative life of termites differs in important respects from that of wasps, bees and ants, whose societies are matriarchal institutions in which males are tolerated only because a few are needed periodically for the purpose of procreation. Hence they are found in the nests only for a short time and in small numbers. Termites, on the other hand, make full use of all available sources of labour. They are vested with the ability to check or modify the development of their young after hatching so that forms which are indistinguishable when they leave the eggs subsequently become either sexless individuals of various grades or perfectly developed males and females, according to the requirements of the community.

By what means this end is achieved is still largely problematical. While social wasps, bees and ants undergo a very complete metamorphosis during which they are sedulously nurtured by adult members of their community, the young of termites emerge from the eggs as active, six-legged creatures, capable of fending for themselves. It is true that they are frequently fed and caressed

by their elders ; but to what extent these attentions serve to modify their development is uncertain. Some authorities believe that the differences between the castes are determined in the eggs, at least in so far as the fertility or sterility of the forms are concerned ; but that feeding and nurture play an indispensable part in the process is highly probable, while it has yet to be shown that these amazing insects do not practise methods comparable to massage and plastic surgery.

The majority of the sexually perfect individuals have wings when adult, but—like the true ants—discard them soon after the nuptial flight. The severance is rendered comparatively easy by the presence near the base of the organ of a transverse suture, or line of weakness, where the wing snaps off readily, leaving a small horny flap projecting from the insect's thorax. Some, however, never develop wings, and are held in reserve within the nest in case any accident should happen to the reigning royalties, upon whose continuing functioning the maintenance and increase of the population depend. Among the more highly specialized species only a single egg-laying female is present in the colony at one time. In preparation for the discharge of her maternal office she undergoes a remarkable post-metamorphic growth—a phenomenon almost unknown among insects, except the repletes of the honey-ants—due chiefly to an extension of the soft integument between the hard, chitinous parts of the abdominal exo-skeleton to accommodate the increase in number and size of the ovaries. The particular male, or king, whose duty it is to fertilize the queen is immured with her in a specially constructed chamber at the centre of the nest, where mating takes place—not once, as in the case of the hive-bee, but at intervals as long as the reproductive capacity of the queen persists.

In the most elaborately organized societies the principle of division of labour is carried to extraordinary lengths. As many as sixteen distinct types or castes have been described, though it is not certain whether all these ever occur together in the same nest. The sterile individuals fall into two classes, the workers and the soldiers. The latter are recognizable by the relatively enormous size of their heads and jaws, these being often grotesquely shaped and useless for feeding, so that their owners are forced to rely for sustenance upon the good-nature of passers-by. Soldiers of one

type have the front of the head drawn out as a sort of rostrum or beak from a frontal pore of which a caustic solution is discharged at the enemy—a peculiarly odious form of chemical warfare already referred to in the last chapter. The sole duty of members of the soldier class is to defend the community, and when need arises they certainly employ their huge jaws and poison-squirting snouts with devastating effect; but they render also an important service by blocking entrances to the nest with their massive heads, so that would-be intruders are kept out. The workers are responsible for foraging, feeding, nursing, building and repairing, while a contingent of both workers and soldiers is always on duty within the royal chamber.

The wingless king is not an imposing figure; but before her reign is far advanced the queen becomes a truly amazing object. In the case of the West African warlike termite her colossally swollen abdomen may weigh anything from 1,500 to 2,000 times as much as the rest of her body, and her laying capacity has been estimated at 36,000 eggs in twenty-hour hours—which works out at a total of thirteen million annually! The following graphic description of a peep into the royal chamber of this species is from the pen of K. Escherich, the first naturalist-explorer to report on its habits. “In the background lay the enormous queen, three inches long, and so thick that she was pressed tightly between the floor and ceiling. She was motionless, except for a series of waves moving rearward along her swollen abdomen. By her side stood the king, a dwarf compared with his mate. . . . Now and then he pressed against his consort’s sides or tried to crawl upon her. The royal pair were surrounded by hundreds of small workers, some running round as if in a circus, others reaching out from floor and ceiling to brush and lick the king and queen. The queen’s head, thorax and legs were covered with little workers, busily grooming, caressing and feeding her. At the opposite end of her body the scene was still livelier. At intervals of from one to three seconds a tiny, long oval egg issued from the tip of the abdomen and was immediately seized by a worker, cleaned, and carried away to one of the surrounding egg-chambers. These operations were performed with a regularity that suggested the work of a factory. When we consider that a termite queen probably lives for ten years or longer, and devotes half her life to egg-laying, we can

form some idea of her prodigious fertility and of the number of her subjects.”

The above remarks refer specially to the relatively few species of termites whose habits have been studied more or less closely by competent observers during the past half century. That fresh and perhaps startling discoveries in this field of research will be made in the not too distant future may be confidently anticipated. At present we know virtually nothing of the manner in which these astonishing insects communicate with one another, while the precise manner in which their strangely diverse castes originate is still obscure.

Termites differ widely in the character of their habitations and architectural achievements. Apart from a few exceptional species they avoid all contact with sunlight and free air. Some species simply burrow within the decaying stumps or branches of trees, but others rear structures so enormous as profoundly to modify the appearance of the landscape when they occur in numbers. The warlike termite already referred to erects conical hills which sometimes attain a height of from six to ten feet, with a circumference of from twenty-three to thirty-three feet at the base, while certain Australian termites build towers taller than a one-storied dwelling-house. These latter structures are usually very slender and strengthened with pilasters or buttresses. Another Australian species, known locally as the “compass ant”, sets up inverted wedge-shaped domiciles of dark grey concrete from four to five feet high which look like so many tombstones in a churchyard; but their chief peculiarity is that they—like the mounds thrown up by our native yellow ant described in the preceding chapter—have always the same orientation, the long walls of the wedge facing almost exactly north and south. Other species of termites are arboreal and build hanging nests among the branches of trees, while still others excavate extensive galleries and chambers in the soil, often extending their operations far below the surface. In desert regions some sink vertical shafts to a depth of many feet in order to obtain the water needed to keep the atmosphere of the nest moist.

The building materials used by termites consist in the main of wood and earth, very finely divided and mixed with the cement-like secretions of their salivary glands. This combination, when it

has solidified, becomes astonishingly hard, and some of the large termitariums, as they are called, can only be broken open by means of explosives. The internal arrangements of these massive structures are always similar, the royal apartment occupying a central position, surrounded by a series of concentric shells, with many chambers in the intervening spaces, while most of the tall, domed nests consist of several stories.

The crude building materials are invariably eaten before being used—a procedure which ensures a thorough trituration and mixing in the crop, as well as the extraction of any nourishment that they may contain. For termites are frugal, almost to a fault. Not only do they subject the ingredients of their concrete to a preliminary digestive process: they habitually consume the same food over and over again until its nutritive value is completely exhausted. Moreover, they maintain a spotless cleanliness in their abodes by sedulously swallowing refuse of every kind, and finally building all desiccated excreta into the fabric of the nest. This intensive thriftiness, coupled with their extremely retiring habits, probably goes far to explain the outstanding success of these feeble creatures in the struggle for existence.

The staple diet of many termites consists of dead wood and decaying vegetation, and like most other wood-feeding insects that have been closely studied their alimentary canal is tenanted by vast numbers of “microbes”—in this instance protozoa of a type found only in such situations. These animalcules, by acting upon the cellulose that is the chief constituent of woody tissues, convert it into carbohydrates readily assimilable by their hosts, they themselves receiving food and shelter in return (so to say) for their services—a clear case of benefits derived and conferred, termed symbiosis by biologists. But dead wood, at best, is a meagre diet, and termites have evolved some strange expedients to make good its deficiency. They have recourse, for example, to the secretions of their own salivary glands, which are richly nutritive. A tiny globule makes its appearance in the mouth, and when it has increased to about one millimetre in diameter it is either swallowed, used for building operations or—if the insect is neither hungry nor in the mood for work—passed on as a *bonne-bouche* to a companion. The royal couple, especially the queen, are fed exclusively with this pabulum, which is also given to the

youthful members of the community ; but they receive in addition thoroughly chewed and probably partially digested wood from the fully grown workers. Another quaint habit of termites is that they continually lick off the surface secretions of each other's bodies, those of the reigning queen being especially relished. They also devour all the sloughed skins of the developing brood, and any deformed or wounded individuals. By consuming food regurgitated by their elders, or by eating their faeces, the young become infected with the intestinal protozoa necessary for their welfare, while excremental material is carried by the winged princes and princesses when they leave the nest for the marriage flight.

Like the true ants, certain of the more advanced species of termites have made the discovery that they can "grow mushrooms", for which purpose the workers heap up spongy, yellowish masses of wood-pulp—or, in some instances, specially cut pieces of grass or leaves—in the larger chambers of their nests ; and these beds soon become plentifully dotted with white fungoid fructifications of a peculiar kind unknown apart from termite cultivation. In this way a supply of concentrated food is obtained, which is said to be reserved chiefly for the brood. When the piles of wood-pulp or vegetable matter become exhausted they are removed and replaced by fresh supplies. According to G. D. Haviland, the workers of the grass-cutting termite of Natal issue from the subterranean nests during the heat of the day and with their strong jaws cut grass into two-inch lengths which they stack at the entrance to their burrows, often leaving them thus until the evening before carrying them underground. When acacia bushes are growing in the neighbourhood they make use of their leaves as well as of grass.

Termites, like true ants, are remarkable for the large number of commensals of one kind or another resident in their nests, a high percentage of which are not merely tolerated but fed and cherished to an extent that has deprived them of all independence and initiative. Most of the latter are small beetles, but the category includes a few flies which have discarded their wings and accustomed themselves to live in total darkness. The degeneracy resulting from the excessive solicitude bestowed on them by their hosts is vividly portrayed by Sir J. Arthur Thomson in the following

passage. "Many of them suffer from physogastry, an ugly word for an ugly thing—the diseased condition that sets in as the penalty of being petted. In some cases the guest undergoes a sorry change. The posterior body or abdomen becomes bloated in an ugly way and may be protruded upwards and forwards over the front part of the body, whose size is often reduced. The food canal lengthens and there is a large accumulation of fatty matter. The wings fall off. The animal becomes more or less blind."

As with the true ants, new colonies of termites normally originate from the relatively few princes and princesses that survive the nuptial flights which take place at set seasons when these young royalties issue from the nests of the locality, literally by millions, through openings specially prepared for the occasion by the workers. It is said that those of some species also construct commodious vestibules or "waiting-rooms" near the exit-holes in which the winged forms of both sexes congregate before the exodus; after which the openings are carefully closed. Insectivorous beasts, birds and reptiles, to say nothing of huntress-wasps and other small fry, avail themselves greedily of the periodic banquets thus provided, so that only a small percentage of the vast swarms escape destruction; but this remnant suffices to carry on the race.

The courtship ritual varies in different species. In one, the male seizes the female during flight, losing his wings simultaneously; but usually the sexes come separately to earth and after discarding their wings at the line of weakness already referred to run rapidly here and there. When a female meets and approves a male they set off, he following her, in search of a suitable nesting site. Eventually a small chamber is excavated, either in decaying wood or in the soil, and in this the couple barricade themselves; after which, for some unexplained reason, they discard their antennae. Only then, or it may be a few days later, does mating take place for the first time. The earliest batches of young are nourished entirely by the parents, especially the queen, on predigested food—a sort of salivous pap. This, in the case of the most highly specialized species, such as the African warlike termite, is elaborated from food reserves stored in their own bodies eked out with material derived from the disintegrated wing-muscles.

Ever since mankind began to explore and colonize he has found termites a source of unparalleled exasperation and material loss, for in all tropical countries they rank among the most formidable pests. Only the hardest metals and stone appear completely to daunt them. It is even said that they can corrode glass with the aid of their saliva. Years ago, a species of termite introduced accidentally to the island of St. Helena increased and multiplied to such an extent that Jamestown was in a short time reduced almost to ruins. In like manner these insects destroyed the Governor's palace at Calcutta and a ship lying in Bombay harbour. Wherever they pass they leave a trail of destruction. Dry food-stuffs, clothing, books and papers are attacked, while woodwork of all kinds is speedily destroyed.

The damage done by termites to woodwork, though often accomplished extremely rapidly, is singularly insidious. Many stories are current in illustration of this point. A well-authenticated instance relates to an officer of the old Indian Army who inadvertently left a cricket bat lying on the ground overnight. When he returned next morning to retrieve his property it crumbled to dust in his hands. During the Second World War crates of military stores stacked temporarily on the ground in New Guinea fell to pieces when moved several weeks later. Such incidents, which might be multiplied almost indefinitely, are characteristic of attack by termites. Physically a feeble folk, much preyed upon by insectivorous enemies, they expose themselves as little as possible to the light of day, moving to the objects of their desire through tunnels and covered ways. Thus, in tropical countries, it is no uncommon happening for doors, window-frames and furniture to collapse without warning. Termites have been known to gain access to a table from the flooring through its legs, and to consume the whole of its interior, leaving intact only a thin outer shell, without once betraying their presence. Covered runways are always constructed to connect the nests of arboreal termites with the ground, the topmost branches of the trees, and other places of call, so that the inhabitants can traverse a wide area without being seen.

Because of their hidden mode of approach termites are able, without attracting notice, to reach the woodwork of a house even when its ground-floor is based on concrete supports. The

only certain safeguard against attack is thoroughly to soak all structural timber in an approved chemical deterrent, of which several are on the market.

In the economy of nature termites are not without their use. Like earthworms and wood-feeding insects in general they render an important service by incorporating dead and decaying vegetable matter with the soil, which is thereby enriched—thus accelerating a process that in hot, dry climates would otherwise be slow. Moreover, soil formed from the pulverized shells or outer walls of the large nests is said to be exceptionally fertile.

Chapter Nine

SOCIAL INSECTS AS PETS

ALTHOUGH the social insects—more especially the bees and ants—have engaged the attention and fired the imagination of thoughtful men for thousands of years past, little in the way of experimental enquiry into their economy and behaviour was attempted prior to the nineteenth century, and even to-day much remains to be done in this fascinating field of biological research. Investigation of the required kind need not be left solely to the specialists. On the contrary, the amateur or spare-time enthusiast, by using his or her faculties for observation and clear thinking, may reasonably hope to make worthwhile, if not outstandingly important, discoveries. A bee-hive or an ant-colony suitably housed is just as easy to keep as a pet dog, cat or canary, and affords well-nigh inexhaustible scope for interesting study.

Observation hives accommodating small communities of bees are not novelties. They have been in use for more than half a century and are obtainable from several London stores. Briefly, they are made to carry one, two or three of the regulation “frames”, but have glass sides instead of the usual wooden ones. Miniature hives are also obtainable. Darkness for the inmates when they are not actually being watched is secured by blinds or screens, while access to the outdoor world is made possible by a tube connected with a one-inch hole in the nearest window-sash. Through this the bees go forth to their labours among the flowers, and return laden with nectar and pollen. In short, the owner of the hive is able at will to witness the building of comb, the egg-laying of the queen, the storing of honey, and all the other intricate details of bee-life without the risk of being stung or in any other way inconvenienced by the comings and goings of the insects.

Anyone with a little knowledge of carpentry can construct an observation hive at small expense by converting one or two old wooden boxes. The measurements of the regulation frames, etc., can be obtained from any handbook on bee-keeping, which will

also supply information on the subject of installing a swarm of bees in its new home. But unless the would-be student has had some practical experience in this matter he will be well advised to enlist the aid of an established apiarist. Once the bees have settled down with their queen they will give no further trouble, will prove a constant source of pleasure, and may well be profitable to some extent. Even in big cities, where bees are restricted to the limited number of flowers to be found in window-boxes, back gardens and the ornamental beds of parks and open spaces, they often contrive to amass honey in considerable quantity. For experimental purposes—e.g. to find the number of foraging trips made during the hours of daylight by a worker—individual bees may be marked with tiny spots of paint of different colours applied to the thorax with a fine brush while they are entering or leaving the hive.

Owing to their easy-going and tolerant disposition humble-bees lend themselves readily to observation. In his book dealing with these insects F. W. L. Sladen has shown that by the use of specially constructed boxes suitably placed the queens may often be induced, like birds, to build their nests in desired places where they may be studied at leisure. The present writer has found that a newly established colony of carder-bees transferred bodily at night to a wooden hutch or hive provided with a hinged lid and a one-inch entrance hole quickly settled down, and after a few trial flights successfully memorized the whereabouts of their new quarters. Nests of the subterranean species, carefully disinterred, may be similarly treated, but their occupants are less easily satisfied.

O. H. Latter made repeated attempts to induce queen wasps to continue their building operations in partial captivity by transferring their little nests while the makers were within to boxes provided with facilities for free entry and exit, but without success. They seemed to resent any interference with their homes, and promptly deserted them. But when once the workers have been reared in sufficient numbers to take over the responsibility for enlarging and repairing the fabric, removal of the nest to a glass-sided cage does not cause any cessation of their activities. The most suitable social wasps for this purpose are the arboreal species, because they do not object to a reasonable amount of

light, and their nests are more easily taken than those which are built in holes. They should be removed in the late evening when most of the wasps will be in residence by cutting through the branch to which they are attached with as little vibration as possible. A wise precaution is to surround the entire nest with a muslin bag, while for additional self-protection gloves may be worn and a veil of black net—similar to those used by bee-keepers—as a safeguard for the head and face. Just before shutting the nest into its observation cage a portion of its outer cover may be stripped off. This provides immediate and congenial employment for the inmates in their new environment, besides enabling their captor to witness their methods of work on a fairly large scale. In the opinion of E. L. Ormerod the most indefatigable builders among our British social species are the workers of the Norwegian wasp. Those of a colony whose nest had been destroyed set about replacing it immediately, and evinced so much zeal that many of them garnished neighbouring twigs with scraps of paper “till the new nest was far enough advanced for all the wasps to find space to work at, or an end to join on to.”

The simplest contrivance for keeping ants under observation is known as the “Lubbock formicarium”. It consists essentially of two sheets of window glass kept from actual contact by narrow strips fixed with crockery cement round the edges of the lower sheet, these being just thick enough to allow the occupants freedom of action, but not so thick that they can hide themselves by piling up earth, as they will do if given the chance. One of the strips is about an inch shorter than the others, leaving a small door, which is closed by a plug of cotton wool, except when needed for the insertion of food or moisture. The formicarium is stocked by taking it to a nest in the open and by means of a small spoon quickly transferring a number of ants, together with some soil, to the lower sheet of glass ; after which the cover sheet is put on and clamped down with metal clips. Alternatively, the edges may be bound with waterproof adhesive plaster. If a queen ant—recognizable by her greatly superior size—is not seen among the others when the colony has had time to settle down in its new quarters, one must be captured separately and introduced through the door.

The best ants for keeping between sheets of glass are the two

small yellow and black species. They need only the minimum of attention. Once a month during the hot weather—perhaps once a fortnight when the atmosphere is very dry—the formicarium should be gently tilted so that about a teaspoonful of water can be poured in. Afterwards a little honey should be inserted before the cotton wool plug is replaced. With this small periodic supply of food and moisture the ants will be maintained indefinitely in a state of contentment and health ; while in winter they need nothing at all, for the cold weather renders them inactive.

These glass containers may be stored for convenience in shallow wooden trays and covered with opaque cloth or paper when not under observation, since ants dislike light in their dwellings. Still better, they can be made to fit into ordinary photographic printing frames, the springs of which have been somewhat weakened by bending so as to allow for the extra thickness of glass. If this plan is adopted it is possible to grant the inmates a measure of liberty by leaving their door open and cutting a notch at one end of the frame down to the flange upon which the glass rests. The formicarium can then be supported on four legs in a dish of water to which an inclined plane leads down. Food, in the shape of a little honey, can be smeared on this occasionally, while the ants will also use it to fetch and carry moisture to their nest.

Several modifications of the Lubbock formicarium are in use. One, devised by W. C. Crawley, is an improvement on the original type because it retains the moisture so necessary for the ants' well-being for a much longer period, and so can be safely left unattended during a holiday. It consists of two rectangular panes of plate glass, about $\frac{1}{4}$ in. thick, with strips of the same, $\frac{3}{4}$ in. wide, cemented round the edges of the lower one, forming a shallow tray into which enough liquid plaster of Paris is poured to reduce the space between the glass panes to $\frac{1}{8}$ in. A layer of fine earth is spread over the plaster while it is still wet, after which the ants may be introduced and the cover glass fixed in place. These nests can be made of any desired size, either square or oblong, and may be divided into two communicating chambers—one without earth and kept constantly lighted to serve as a feeding and exercise ground. The activities of an ant colony that has made itself at home in a glass-roofed enclosure can be easily watched at

any time during the day or night through a screw-focussing tripod magnifier. The inmates will be seen collecting and carrying off the eggs laid by the queen, tending the larvae and sorting them according to age, and assisting the pupae to free themselves from their wrappings. If by good fortune one has entrapped along with the ants any myrmecophiles—i.e. their guests, lodgers or parasites—the differing treatment accorded to them can be studied and recorded, and their specific life-histories worked out.

For the reception of the larger species, such as the wood-ant with a sufficient quantity of their natural nest material Donisthorpe invented a large container similar in appearance to a small vivarium such as is used for the accommodation of lizards, etc. His description is as follows: "The framework is made of wood, 14 in. in height, breadth and length, standing on four legs 4 in. high. Four panes of glass 12 in. square fit into grooves in the wooden frame, and form the sides. The bottom is made of perforated zinc, over which is laid a thick layer of plaster of Paris, and the top is left open. This nest stands in a large zinc tray, the outside of which consists of a trough to hold water about an inch and a half wide and two inches deep. Between the sides of the legs of the nest and the trough there is a space about two inches wide. A layer of sand, five or six inches deep, is placed over the plaster in the nest."

To stock such a nest a quantity of ants together with their building material is emptied into it, just as collected, from the bag in which it was brought home, care being taken that at least one queen has been secured. The captives soon start tunnelling operations in the sand and pile up the pine needles and small twigs—fresh supplies of which may be thrown in from time to time—to form the characteristic mound over their workings. They bring the eggs and larvae to the inside of the glass pane nearest to the sun or the warmth radiated from a fire, and use the corners of the zinc tray for cemeteries and refuse dumps. Thus, much may be learnt about their habits, while it is always possible that some guest or lodger not previously identified may make its appearance.

For many years past a nest of the wood-ant has figured as a popular exhibit in the Insect House at the London Zoo. It is staged about waist high behind glass, and consists of two rectangular

shallow basins, formed of cement on a zinc base and surrounded by a shallow moat three or four inches wide. Each basin is filled with loamy soil in which some grass is rooted, while twigs, bits of bark, dead leaves, etc., are strewn on the surface. On one of these islands the actual nest is situated, on the other additional building material and food are placed. A small log or piece of crazy paving bridges the moat between the two, across which the ants pass to and fro about their business. A television screen enlarger, placed in front of the main food supply, affords a fine view of their foraging activities.

Wood-ants, in common with all the larger species, are omnivorous, and in addition to the usual rations of honey or syrup must be supplied periodically with dead insects, small quantities of finely minced lean meat, or dry fish-food. They will also pick clean any bones to which they have access.

The Rev. J. G. Wood, a voluminous exponent of popular natural history during the latter part of the nineteenth century, hit upon an ingenious method of witnessing what goes on in an ants' hillock. He and a friend, standing opposite each other, cut one completely in two by means of a large sheet of plate glass, which was left buried in a vertical position. After the expiration of a few weeks, when the ants had had time to repair the damage, one side of the hillock was removed with a spade, so that the glass served as a window, allowing the undisturbed interior to be inspected. The most satisfactory view is obtained when the glass is inserted with its plane exactly east and west and the window exposed on its south side on a hot, sunshiny day; otherwise moisture is apt to condense on the glass, quickly rendering it more or less opaque.

GLOSSARY

List of English names of insects mentioned in this book
with Latin names appended.

- Acacia-thorn Ant (*Pseudomyrma bicolor*).
Adamson's Bee (*Apis adamsoni*).
Ant Lion (*Myrmelion formicarius*).
Ants'-nest Fly (*Microdon mutabilis*).
Antler Moth (*Cherapteryx graminis*).
Ambrosia Beetles (*Ipinae*).
Argentine Ant (*Iridomyrmex humilis*).
Argentine Executioner Ant (*Labachena* sp.).
Army Worm (*Sciaria militaris*).
Autumn House-fly (*Musca autumnalis*).
- Bark Beetles (*Scolytidae*).
Bee-louse (*Braula coeca*).
Bee-mite (*Acarapis woodi*).
Bees (*Anthophila*).
Beetle-killer Wasps (*Scoliides*).
Black Ant (*Lasius niger*).
Black Beetle, *see* Common Cockroach.
Black Borer Wasp (*Trypoxylon figulus*).
Black-veined Brown Butterfly, *see* Monarch Butterfly.
Blood-red Ant (*Formica sanguinea*).
Book-louse (*Liposcelis divinatorius*).
Bot-fly of Horse (*Gastrophilus intestinalis*).
Bread Beetle, *see* Paste Beetle.
Brimstone Butterfly (*Gonepteryx rhamni*).
Brown-tail Moth (*Euproctis chrysorrhoea*).
Buff-tailed Humble-bee (*Bombus terrestris*).
Bull-dog Ants (*Myrmecia* spp.).
Burying Beetles, *see* Sexton Beetles.
- Carder-bee Fly (*Criorrhina floccosa*).
Chafer Beetle—large (*Melolontha melolontha*).
Cinnabar Moth (*Callimorpha jacobaeae*).
Cluster Fly (*Pollenia rudis*).
Cockroach—common (*Blatta orientalis*).
Common Clouded Yellow Butterfly (*Colias croceus*).
Common Honey Moth (*Achroia grisella*).
Common Wasp (*Vespula vulgaris*).
Corn Weevil (*Sitophilus granarius*).
Cuckoo Wasp (*Vespula austriaca*).

- Dark Guest-ant (*Anergates atratulus*).
 Death's-head Moth (*Acherontia atropos*).
 Desert Locust (*Schistocerca gregaria*).
 Devil's Coach-horse (*Staphylinus olens*).
 Dingar, *see* Indian Bee.
 Driver Ants (*Dorylus spp.*).
 Drone Fly (*Eristalis tenax*).
 Dung Beetles (*Scarabaeidae*).
- Earwig (*Forficula auricularia*).
 Eastern Bee, *see* Indian Bee.
 Egg-carrying Water-bugs (*Zaitha spp.*).
 European Amazon Ant (*Polyergus rufescens*).
 Executioner Ant (*Bothriomyrmex decapitans*).
- Fever Fly (*Dilophus febrilis*).
 Field Digger-wasp (*Mellinus arvensis*).
 Fire Ant (*Solenopsis sp.*).
 Fire Bug (*Pyrrhocoris apterus*).
 Flour Beetle (*Tribolium confusum*).
 Foraging Ants (*Eciton spp.*).
 Four-spotted Clythra Beetle (*Clythra quadrimaculata*).
 Four-spotted Darter Dragon-fly (*Libellula quadrimaculata*).
 French Polistes Wasp (*Polistes gallicus*).
 Frog-hopper Wasps (*Gorytes spp.*).
- Garden-Ant, *see* Black-Ant.
 Goat Moth (*Cossus cossus*).
 Gold-tail Moth (*Euproctis similis*).
 German Wasp (*Vespula germanica*).
 Giant Bee (*Apis dorsata*).
 Grass-cutting Termite (*Termes angustata*).
 Green-shaded Honey Moth (*Aphomia colonella*).
- Hairy-footed Bee (*Anthophora pilipes*).
 Hairy-legged Mining-bee (*Dasypoda hirtipes*).
 Harvesting Ants of Texas (*Pogonomyrmex spp.*).
 Heath Potter Wasp (*Eumenes coarctata*).
 Heath Sand Wasp (*Ammophila campestris*).
 Herald Moth (*Scoliopteryx libatrix*).
 Hive-bees (*Apis spp.*).
 Honey Ants (*Myrmecocystus spp.*).
 Hornet (*Vespa crabro*).
 Hornet-like Robber-fly (*Asilus crabroniformis*).
 Hornets'-nest Beetle (*Emus hirtus*).
 Hornets'-nest Fly (*Volucella inanis*).
 Horse-Ant, *see* Wood-Ant.

Honeycomb Moth (*Galleria mellonella*).
 Honey Wasps (*Nectarinia spp.*).
 Horn-tails (*Siricidae*).
 House Cricket (*Gryllulus domesticus*).
 House-fly—common (*Musca domestica*).
 Humble-bee Fly (*Volucella bombylans*).
 Humble-bees (*Bombus spp.*).

Indian Bee (*Apis indica*).
 Italian Bee (*Apis ligustica*).

Jet Ant (*Lasius fuliginosa*).

Lackey Moth (*Malacosoma neustria*).
 Ladybird Beetles (*Coccinella spp.*).
 Large Blue Butterfly (*Maculinea arion*).
 Large White Butterfly (*Pieris brassicae*).
 Lawn Bee (*Andrena fulva*).
 Leaf-cutting Ants, *see* Sauba Ants.
 Leaf-cutting Bees (*Megachile spp.*).
 Least Mining Bee (*Halictus minutissimus*).
 Little Bee (*Apis florea*).
 Little Robber Ant (*Solenopsis fugax*).
 Long-horn Bee (*Eucera longicornis*).

Marsh Fritillary Butterfly (*Euphydryas aurinia*).
 Mason Bees (*Osmia spp.*).
 Mason Bee—European (*Chalicodoma muraria*).
 Matabunter Wasps (*Chartergus spp.*).
 May-bug (*Melolontha melolontha*).
 Meadow-Ant (*Formica pratensis*).
 Mealworm Beetles (*Tenebrio molitor* and *T. obscurus*).
 Mediterranean Harvesting Ants (*Aphaenogaster spp.*).
 Midges (*Chironomus spp.*).
 Milkweed Butterfly, *see* Monarch Butterfly.
 Minotaur Beetle, *see* Trident-bearer Beetle.
 Monarch Butterfly (*Danaus plexippus*).
 Mosquito Bees, *see* Stingless Bees.
 Mottled-winged May-flies (*Ephemera vulgata* and *E. danica*).
 Mouse Moth (*Amphipyra tragopoginis*).

Negro-Ant (*Formica fusca*).
 Nigerian Ant (*Tapinoma nigerrimum*).
 Norwegian Wasp (*Vespula norvegica*).

Oil Beetle (*Meloë proscarabaeus*).
 Old Lady Moth (*Mormo maura*).

Onion Fly (*Delia antiqua*).

Painted Lady Butterfly (*Vanessa cardui*).

Pale Clouded Yellow Butterfly (*Colias hyale*).

Paradoxical Beetle (*Metoecus paradoxus*).

Paste Beetle (*Stegobium paniceum*).

Peacock Butterfly (*Nymphalis io*).

Pellucid Drone-fly (*Volucella pellucens*).

Pharaoh's Ant (*Monomorium pharaonis*).

Pin-hole Beetles, *see* Ambrosia Beetles.

Processionary Caterpillar of Fir (*Cnethocampa pithyocampa*).

Processionary Caterpillar of Oak (*Cnethocampa processionea*).

Red Admiral Butterfly (*Vanessa atalanta*).

Red-banded Sand Wasp (*Ammophila sabulosa*).

Red Mason Bee (*Osmia rufa*)

Red-tailed Cuckoo Humble-bee (*Psithyrus rupestris*).

Red-tailed Humble-bee (*Bombus lapidarius*).

Rhinoceros Beetle (*Oryctes nasicornis*).

Rice Weevil (*Sitophilus oryzae*).

Robber Flies (*Asilidae*).

Rose Beetles (*Cetonia aurata* and *C. floricola*).

Ruby Wasps (*Chrysididae*).

Rufus Wasp (*Vespula rufa*).

St. Mark's Fly (*Bibio marci*).

Sauba Ants (*Atta spp.*).

Sexton Beetles (*Necrophoridae*).

Shield-bug of Birch (*Elasmotethus griseus*).

Shining Guest Ant (*Formicoxenus nitidulus*).

Shot-borer Beetle (*Anisandrus dispar*).

Silver Fish Insect (*Lepisma saccharina*).

Small Ermine Moths (*Hyponomeuta spp.*).

Small Tortoiseshell Butterfly (*Aglais urticae*).

Small White Butterfly (*Pieris rapae*).

Social Wasps (*Vespinae*).

Solitary Wasps (*Eumenidae*).

Spider-killing Wasps (*Pompilidae*).

Spinning Ants (*Oecophylla spp.*).

Spiny Mason Wasp (*Odynerus spinnipes*).

Spruce Aphid (*Adelges abietis*).

Stingless Bees (*Meliponidae*).

Swift Darter Wasps (*Oxybelus spp.*).

Tree Wasp (*Vespula sylvestris*).

Trident-bearing Beetle (*Ceratophylus typhaeus*).

Turf-Ant (*Tetramorium caespitum*).

Two-coloured Osmia Bee (*Osmia bicolor*).

Two-spot Ladybird (*Coccinella bipunctata*).

Velvet Ant (*Mutilla europa*).

Wandering Cuckoo Bees (*Nomada spp.*).

Warlike Termite (*Termes bellicosus*).

Wasps—True (*Diploptera*).

Wasps'-nest Fly (*Pegomyia inanis*).

Webbing Clothes Moth (*Tineola bisselliella*).

Web-spinners (*Embioptera*).

Whirligig Beetles (*Gyrinus spp.*).

White-speck Wainscot Moth (*Leucania unipunctata*).

Winter Gnat (*Trichocera hiemalis*).

Wood-Ant (*Formica rufa*).

Wood-Ant Moth (*Myrmeconella ochracea*).

Wood Wasp, *see* Tree Wasp.

Wool-carder Bee (*Anthidium manicatum*).

Yellow Ant (*Lasius flavus*).

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