Chapter 2

The basic biology of *Apis mellifera*, the western honeybee

2.1 Introduction

Honeybees and silk-worms are the only two insect species directly exploited by man. Of the two species, the honeybee has by far the more elaborately organised life. Moreover this organisation has been surprisingly little altered by the "domestication" of the bees. For once the Law is right in classifying bees as animals *ferae naturae* — of a wild nature.

A great deal is now known about how a honeybee colony functions, and to keep bees successfully and pleasurably it is very useful to know as much about this as possible. What follows is an outline of the principal facts. If you become a bee-keeper, then it will be your pleasure to amplify this knowledge, by wider reading, by listening to your fellow bee-keepers, and by direct observation. Although the bees have not read any of the books, it is likely that they will in the end prove to be your most valuable teachers.

2.2 The place of the honey bee in nature

The scientific classification of living creatures initiated in the eighteenth century by Linnaeus places honey bees in the scheme (which is now tied to Darwin's theory of evolution) like this:—

KINGDOMS	Animal	Plant	...	
PHYLA	*Arthropoda*	*Mollusca*	*Chordata*	...
CLASSES	*Insecta*	*Crustacea*	...	
ORDERS	*Hymenoptera*	*Diptera*	*Coleoptera*	...
SUPERFAMILIES	Bees (*Apoidea*)	Ants	Wasps	...
FAMILIES	True bees	Leaf-cutters	Miners	Plasterers
	(*Apidae*)	(*Megachilidae*)	(4 families)	(*Colletidae*)
GENERA	Honeybees	Bumblebees	...	
SPECIES	Western honeybee	Eastern honeybee	Giant honeybee	Little honeybee
	Apis mellifera	*Apis cerana*	*Apis dorsata*	*Apis florea*

In the fossil record the *hymenoptera* first appear about 150 million years ago in the Jurassic period, or, as some others claim, 225 million years ago in the Mesozoic period. Bees first appeared about 26 million years ago, at the same time as the majority of flowering plants. This is no coincidence. Flowering plants need a mechanism whereby the pollen (male reproductive cells) can be transported to another plant of the same species to fertilise the female reproductive cell and form a fertile seed.

Many plants use the wind, notably most of the grasses, which is why their pollen is such a common cause of hay fever. But many insects feed on plants, and their ability to move from plant to plant has allowed the plants to evolve flowers with *nectaries* which secrete the sugary fluid nectar as a deliberate attractant for the insects. The pollen which is dusted on to the feeding insects is then spread by them from plant to plant, as the plants require.

Nectar is an excellent source of carbohydrate (energy food) and pollen itself is a source of protein (body-building food). The bees and the flowering plants have thus evolved in co-operation with one another. The bees have specialised in exploiting this food source, and live solely on these plant products. Some of the plants have in turn come to rely ever more heavily on such systematic visitors as the bees, and will completely fail to set fertile seed unless they are visited by bees. There is a double cost involved for the plants. First of all the production of nectar involves using up energy which could have been spent in other ways, and secondly there is a risk of failure to set seed if bees do not visit. But these plants find these costs worth paying for the generally reliable pollination service provided.

An example of this plant specialisation is provided by plants of the pea family, the most obvious one locally for our bees being the broom, whose flower relies entirely on being "tripped" by a bee in order to be fertilised.

Among the ants, wasps and bees it is remarkable that from the original solitary forms, socially organised species have evolved in all three superfamilies, with remarkably similar forms of social organisation. The ways of life of these super-families are however fundamentally different. The ants in general are eaters of a wide variety of foodstuffs, although individual species of ants have specialised in many remarkable ways. Wasps usually feed on other insects (or other forms of animal food). Bees, as stated above, specialise in one particular form of plant food. There are exceptions to these general rules in all the superfamilies.

Solitary wasps and bees of numerous species exist. Their general life pattern is that the female after mating prepares a nest, often in an underground burrow, which she stocks with sufficient food of the appropriate kind, and on it she lays her eggs which she then abandons. Many species of solitary wasps use their ovipositors as stings in this process to paralyse but not kill insect food left for their young. This is perhaps the most likely evolutionary origin of the sting present in most wasps and bees. There may be one nest with several eggs, or several nests with one egg each. The eggs hatch into larvae or maggots which live on the food provided, and after growing to adult size pupate — form a chrysalis like a butterfly's. From these the adults of the next generation emerge in due course.

An intermediate stage of social organisation is exhibited by the bumblebees and by the familiar wasps we all know and (generally) hate. A queen (female) which after mating at the end of the previous summer has hibernated alone in a sheltered spot throughout the winter finds a suitable site in the spring. There she builds a small nest in which she lays a few eggs. She herself brings food to the developing larvae, and feeds and tends them. These emerge as sexually imperfect females called workers, who then take over the nursery and feeding duties, the queen confining her activity after that to the laying of ever larger numbers of eggs in a nest which is steadily expanded by the increasing number of workers. At the end of the summer a special generation of eggs is laid by the queen which emerge as sexually mature males (drones) and females (queens). These fly from the nest and mate away from home on the wing, thus avoiding close in-breeding as far as possible as mates from other nests will also be available. The rest of the colony then goes into decline and dies out. It is at this stage that the worker wasps cease to hunt for insect food and become a nuisance to us as in their dying days they seek to assuage their discontent with our plums, pears and jam.

The honeybees, like the ants, have taken social organisation a stage further. They almost certainly evolved in the tropics and subtropical regions, the only regions where the giant honey bee and the little honey bee are found. They store large amounts of honey, which is derived from nectar by a process of concentration and partial digestion. This stored food enables their colonies like ant nests to be perennial.

Instead of individual queens founding new colonies, these are produced from the old one by the process known as *swarming*. The giant and little honeybees have nests consisting of a single comb containing both honey stores and developing bees. Both the western and the eastern honeybees have larger nests — much larger in the case of the western honeybee — of many parallel vertical combs. The amount of stored honey frequently reaches 50 kg (100 lb) or more. This feature has enabled the western honeybee (with the assistance of humans) to extend its range from the tropics to the sub-arctic regions. It has also made it worthwhile for people to exploit it both for its yield of honey and for its unequalled usefulness as an agricultural crop pollinator, since honeybees can be available in reasonably large numbers to pollinate even the earliest spring flowers.

The details of the life-cycle of the western honeybee colony as it has been elucidated by many people over the centuries are explained in the following sections.

2.3 Where bees live

In many places in Scotland even now, colonies of honey-bees live on completely untended — in hollows in stone walls, roof-spaces of buildings etc. This situation is changing however now that the *Varroa* mite has become a widespread problem. It is unfortunately likely to be killing off most wild honeybee colonies unmanaged by beekeepers, though a few do appear to be tough enough to survive.

Before people made buildings, there were many more trees, and hollow trunks of old trees are undoubtedly the honey-bees' natural site for a home. A wild honey-bees' nest contains within the hollow usually from five to twelve honey-combs attached to the under-side of whatever is acting as roof, and hanging down roughly parallel to one another with spaces of about 6 mm (1/4 inch) between them. The combs are about 35 mm ($1\frac{1}{2}$ inches) thick, and consist of roughly horizontal hexagonal cells built of beeswax out on each side from a wax mid-rib.

2.4 The end of summer

In August/September a prosperous colony will have the upper part of all the combs filled with up to 50 kg (100 lb) or more of honey, these cells being sealed over with wax cappings. Some cells lower down the combs will contain pollen, much of it sealed over with a layer of honey. A darker looking area of comb near the bottom centre will contain cells where developing larvae are being reared by the bees to provide the next generation. Some cells near the bottom will be empty.

There will be between 8 000 and 80 000 **worker bees** in the colony, a few hundred **drones** (males), and a single **queen** or sexually mature female which lays all the eggs, but can do nothing else — not even feed herself. Incidentally, the drones too have to be fed by the workers, since they do not know how to feed themselves.

2.5 Stings

All worker and queen honeybees have at their tail end both an ovipositor for laying eggs and a sting. The queen has an unbarbed sting which she never uses except in fighting a rival queen. She mainly uses her ovipositor. Workers normally do not lay eggs, but the worker's sting is a sophisticated barbed weapon which is highly effective against large animals like human beings, for which the stealing of the nutritious honey store is an attractive idea. Bees away from home only sting if they are crushed or hit. Near home, if the alarm is raised, they can become extremely aggressive. Any vibration or waved arms will arouse them at the end of summer when they have much to defend. Hair-spray smells, sweat or whisky breath are also attacked.

The scent of one sting attracts more bees to the attack and the result can be unpleasant and dangerous if you are unprotected. The sting is usually left behind by the bee when she tears herself free, and continues to inject venom by reflex action for up to half an hour. The bee herself dies.

If you are attacked when without protective clothing then:–

- Move away from the colony site/beehive quickly and quietly.
- If bees continue to follow you, go under trees or go indoors.
- As soon as practicable remove the sting by *scraping* it out with a finger-nail or other tool: do not pinch it out or you will inject more venom.
- Do not return to the site without protective clothing or you *will* be stung again.

Most people when stung experience a sharp pain immediately, but if the sting is promptly removed they suffer no further ill effects apart from inflammation and itching of the place for a day or two afterwards. Many people are unreasonably frightened of being stung by bees. There can very occasionally be serious consequences, but it is important to keep a sensible view of these risks.

An excellent and up-to-date explanation for the layman of the medical risks involved is *"Medical Aspects of Beekeeping"* by Harry Riches, MD, FRCP published by Northern Bee Books in 2000. Dr Riches is himself both a doctor and a beekeeper and ex-President of the British Beekeepers' Association who dealt with his own allergy to bee-stings with complete success. I would recommend anyone worried about stings to read this book. In an appendix to this chapter is a brief summary of his main recommendations.

2.6 The casting of the drones

In August/September the number of drones present in the bee colony rapidly diminishes, since with the onset of the colder shorter days, the workers actively eject them to die of cold and starvation overnight when they are excluded. They have no role to play in the winter, and retaining them would reduce the colony's chances of surviving the winter.

2.7 Wintering

As the days shorten, the queen's laying is reduced and stops, the last of the developing larvae — the brood — emerges as worker bees, and the workers in the colony then allow the temperature in the nest to drop from about 33^0C (92^0F) to about 15^0C (60^0F). They become much more lethargic and cluster together in the centre of the nest, just below the main bulk of the honey store, many creeping into the now empty cells where larvae were recently being reared.

Only on warm dry days in winter do a few bees fly to empty their bowels and to collect fresh water.

As winter progresses, the cluster gradually eats its way up through the honey store which was gathered to enable the colony to survive the winter. Food is shared, and by metabolising it, the cluster maintains the temperature at the centre at about 15^0C (60^0F), although in severe frosty weather bees on the outside of the cluster may become chilled and die despite tighter clustering.

2.8 The spring build-up: brood-rearing

With the longer days of February the colony becomes much more active. Workers feed the queen more generously and she begins to lay again in cells at the heart of the cluster. By consuming more honey the workers again raise the temperature to around 33^0C (92^0F) which is the temperature necessary for brood rearing. The colony starts to use up its stores much more quickly and may at this time be in danger of starvation.

The eggs which are only about 1.5 mm ($\frac{1}{16}$ inch) in length are laid upright one per cell at the base. After 3 days larvae emerge and lie coiled at the bases of the cells. The workers immediately begin to feed them. These cells are the *open brood.* Initially their food is "bee-milk" — a glandular secretion produced from glands in the heads of young worker bees which have been feeding on pollen. This food is very rich in protein. After two days, more honey and pollen is added to the diet of the larvae. Five days after hatching the larvae have grown so large that they can no longer lie curled in the bases of their cells. The worker bees then cap these brood cells with a very porous wax/pollen capping of a light brown colour, unlike the white wax cappings of the honey store, and the larvae inside stretch out, defecate, and line their cells with silk cocoons which they spin, and which after many generations largely replace the original wax of the brood cells. They shed the last of their larval skins and become pupae. These cells are the *sealed brood.*

Fourteen days later the pupae have metamorphosed into worker bees which with their powerful jaws bite their way out through the capping and join the colony, where, after an initial feed they take up duty as cell cleaners and nurses of larvae.

2.9 Foraging, colony growth and bee longevity

In March, or even earlier, fine days allow some of the older workers to seek fresh pollen and nectar from early spring flowers to replenish the depleted stores. Bad weather now can spell disaster. A worker which finds a good source of food, on returning home signals its location to her sisters by the *dance language* first discovered in the twentieth century by Karl von Frisch. Thus many workers are quickly directed to any good food source. Water is also collected to dilute the very concentrated winter honey.

As the first of the queen's new brood emerges, the worker population, which may have dwindled to as low as 3 or 4 thousand begins to recover, and brood rearing now begins in earnest. All those workers which started their lives in the autumn are nearing the end of their span, and most will be dead by May, most dying when on foraging trips. Moreover the active summer workers, unlike the somnolent winter ones, only live for about six weeks of adult life. Only the queen has a longer life-span which may be as long as 3 or even 5 years. Spring advances and more plentiful nectar and pollen become available. The large empty areas of comb left by the winter feeding are gradually filled again, with honey above and an expanding brood-nest surrounded by stores of pollen below. At first the honey cells are open and contain a watery nectar, but this is soon ripened and concentrated by the addition of digestive enzymes by the bees, and by the fanning action of their wings which evaporates the excess moisture. When sufficiently concentrated, the honey is again sealed with wax to prevent it from reabsorbing atmospheric moisture on damp days.

At the height of May the queen will lay between 1000 and 2000 eggs per day. The emerging workers pass through a regular cycle of duties, the young ones doing domestic work for 2 to 3 weeks, then moving on to guard duty at the doorway, and finally becoming foragers for nectar and pollen.

2.10 Reproduction: Dzierzon's rule, and drones

Towards the outside edges of the combs there are usually found patches of cells which are slightly larger than the usual standard being 6 mm ($\frac{1}{4}$ in) across instead of 5 mm ($\frac{1}{5}$ in). When the queen has filled the central areas with brood, she starts to lay in these cells.

A remarkable fact was discovered about 1845 by the Silesian bee-keeper Johann Dzierzon. It has since been amply confirmed by many experiments, notably those of Gilbert Barratt of England published around 1919. Also it is now known that a similar phenomenon is found among most of the hymenoptera — ants, wasps, other species of bees etc.

The queen bee on first emerging in her youth does not begin laying until she has been on a *mating flight*, on which she flies up to a height of about 10 m (30 feet), at which height her scent suddenly becomes strongly attractive to drones who spend all fine summer days patrolling in "drone congregation areas" on the look-out for flying queens. The queen mates with about a dozen or so drones in succession, each drone dying in the act. The spermatozoa from the drones' semen then lodge in a special organ in the queen's abdomen called the *spermatheca* where they remain viable throughout her life.

Each egg that the queen lays in one of the smaller cells, she fertilises with some of the spermatozoa that she has stored. But when she lays in the larger cells, she refrains from fertilising the egg. However unlike the eggs of mammals or birds which die if they are unfertilised, these eggs develop. The remarkable fact Dzierzon noted was that *all* the fertilised eggs, which have both a father and a mother, develop into females — workers or queens — whereas *all* the others, which have a mother but no father develop into males — drones. The drones are reared exactly like the workers, but the mature larvae are larger and are covered with a dome-shaped rather than a flat capping, so giving sealed drone-brood the appearance of a lot of bullet ends sticking out from the comb. Their pupation phase lasts for sixteen days instead of fourteen. Because of their origin it is now known that drones are also peculiar in that each cell of their bodies only has half the expected complement of chromosomes in it. They are what biologists call *haploid* organisms.

The operation of Dzierzon's rule also explains how queen bumblebees and queen wasps are able to control the sex of their offspring in order to create initial generations of all-female workers when establishing their colonies in the spring.

2.11 Swarming and the rearing of new queens

When June arrives, if the colony is prospering, the whole nest becomes overcrowded. This often triggers the remaining part of the bees' reproductive cycle. It is clear that in a sense an individual bee is of no account, but that the unit of honeybee life is the colony. This is potentially immortal, but it may perish through accident, disease or starvation. Thus it is essential that there should be a mechanism for increasing the number of colonies. This is provided by swarming.

In late May or early June the workers construct of beeswax five to twenty *queen cups* like inverted acorn cups protruding from the faces and edges of the combs. When conditions are ripe, as determined by the circulating chemical secretions from queen and workers called *pheromones*, the queen will lay a fertilised female egg in each of these. The workers now control the development of the resulting larvae by a specially generous diet of what is called Royal Jelly, the significant component of which was proved by the work of Asencot and Lensky in Israel in the 1970s (*"The effect of sugars and juvenile hormone on the differentiation of the female honeybee larvae"*, Moshe Asencot and Yaacov Lensky, Life Sciences Vol 18, 603–700; *"The effect of sugars and juvenile hormone on the differentiation of the female honeybee larvae (Apis mellifera L.)"*, Thesis submitted for the degree of Doctor of Philosophy by Azencot Moshe to the Hebrew University of Jerusalem, Rehovot, August 1977) to be additional honey. The ideas of the late Barbara Cartland and others that there is some special life-prolonging magic about it are probably nonsense. These larvae grow larger than any others because the special diet stimulates a hormonal trigger in the larvae when they are about 36 hours old and this completely alters their future development. As the larvae grow, the cups in which they are housed are extended into vertical *queen cells* about 25 to 35 mm (1 to $1\frac{1}{2}$ in) in length, with the opening at the bottom. Like other brood cells they are finally capped when the larvae are five days old. The resulting pupae mature more quickly than those of workers or drones, and emerge as virgin queens after a mere 8 days.

In the meantime remarkable things have been happening in the colony. On the first fine day after the capping of the first queen cell, usually around mid-day, great excitement builds up and shortly clouds of workers fly up into the air and hover in front of the nest. They are joined by the queen who usually quickly settles on a nearby branch of a tree or other convenient spot. The masses of swarming workers then gather round her and gradually build up into a dense suspended cluster like a large bunch of grapes — the swarm.

If left to its own devices the swarm will remain in place for perhaps a few hours or a few days. The workers have all filled their stomachs with honey and are placid and content. But scouts from the swarm are away exploring for a new home. Each scout which finds a possible site returns and signals its find by dancing on the surface of the swarm cluster, trying to encourage others to go and look at this possibility. Ultimately the swarm becomes "of one mind" and lifts off to fly in a "bee-line" to its new home. There the workers immediately set to work to clean out rubbish and to build new combs from wax secreted by glands under their abdomens. They work urgently and with haste. They have about two months to build up from nothing a honey store and a young worker population adequate to see them through the winter.

The parent colony has a few days to wait until a young queen emerges. When she does, she may depart with a second smaller swarm or *cast*. A third and even a fourth cast may go, some with several queens, but they become progressively smaller and have less chance of surviving than the *prime swarm*.

Ultimately a queen emerges that the workers allow to take over the old home. Her first task is to seek out any unhatched queen cells or other virgin queens at large. When two meet they fight to the death. This is the only time a queen uses her unbarbed sting.

Thereafter, usually about two to three weeks after the departure of the prime swarm, the virgin queen goes out on her mating flight, and returns to resume after another day or two the interrupted egg-laying and build up again the now much shrunken population.

2.12 Queen production in other circumstances

If a queen becomes old so that her pheromonal secretions are deficient, the bees will supersede her. A small number of queen cells is built, but no swarm departs. The first queen to emerge flies and mates, the workers tearing down the other queen cells and destroying the inmates. The new queen may lay for a time beside her mother, but soon the older queen is neglected by the workers and dies.

If a queen suddenly dies, the workers deprived of her pheromones immediately convert a few cells with young worker larvae into makeshift emergency queen cells and thus save the colony from extinction by raising a new queen. If no young enough worker larvae are present, or if the loss occurs in winter, the colony is doomed.

2.13 Autumn returns

Finally the annual cycle returns to autumn and again the preparations for winter begin with the casting of the drones.

Appendix 2.1 — Developmental details for the different castes of honeybees

It is an essential part of what a bee-keeper must know to remember the developmental times for the different castes, since interpreting what you see, and planning and executing various manipulations depend on this knowledge.

CASTE	WHERE	EGG DAYS	UNSEALED DAYS	SEALED DAYS	TOTAL DAYS
Queen	Queen cell	3	5	8	16
Worker	Small comb cell	3	5	13	21
Drone	Large comb cell (domed capping)	3	6	15	24

Appendix 2.2 — Drone layers

If a queen is prevented by bad weather from taking her mating flight for too long (3 weeks), or if she finds no drones because of the lateness of the season, she may start to lay unmated. She will then never mate and all her eggs will develop into drones. The colony she rules will quickly die out.

If a colony becomes hopelessly queenless, the ovaries of some of the workers are stimulated by the feeding of the other bees who have no queen to feed, and they will then start to lay a few eggs irregularly dispersed through the cells. Again only drones can result as workers are anatomically incapable of mating.

The bee-keeper can detect these conditions in beehives by finding the small-size worker cells sealed with the domed drone cappings. Clearly these colonies require immediate remedial action if they are to survive. Combs which have been used for such irregular production of drone brood will never be used thereafter for satisfactory rearing of worker brood, and have to be scrapped.

Appendix 2.3 — Up to date advice about bee stings

- A severe stinging, involving the reception of many hundreds of stings is a potential hazard to life for anyone, but no beekeeper should ever be in danger of that provided sensible precautions are taken when handling bees.

- Being stung inside the mouth (involving the danger of suffocation due to swelling of the throat) or being stung in the ball of the eye (involving possible loss of the sight of the eye) are hazards that should be avoided by always wearing a veil when handling bees. Incidentally a bee which gets *inside* a veil hardly ever stings. She is always in a panic to get out!

- Normally a sting, if promptly removed, gives a sharp pain initially, which subsides within a minute or so, followed by slight itching for a day or so afterwards. The use of antihistamine cream for this itching is not recommended as it can sometimes set up a dermatitis. If the itching is troublesome, Dr Riches recommends the use of a cold compress or calamine lotion. Most beekeepers do not use anything, as to most people it is less bother than a nettle-sting.

- When a beginner starts to keep bees, the first sting or two provoke little reaction, but a minority go on to experience occasional quite severe swelling locally. Usually this simply subsides after a time as they develop an immunity mediated by the IgG immune response, and thereafter experience little trouble from the occasional sting. If the local swelling is troublesome, Dr Riches recommends taking an antihistamine *tablet* (Piriton (chlorpheniramine)), available over the counter from pharmacists, an hour or so before working with the bees. This can cause drowsiness which can be dangerous if you are going to drive or work with dangerous machinery of any kind. A slightly more expensive alternative in that case is Zirtek (cetirazine), which is less likely to cause drowsiness. Of course before taking any medication you should ensure that you do not suffer from any medical condition that might make it dangerous. Read the instructions!

- A small minority of people develop a severe allergy to bee-stings mediated by the IgE immune response. This can lead to an extremely dangerous anaphylactic reaction in this minority, with breathlessness, nausea, sickness and fainting. Such a reaction must be regarded as a medical emergency, and hospital help sought urgently, since people can die of anaphylactic shock.

- If people who develop a severe allergy to bee-stings wish to continue to work with bees, then immunotherapy with pure bee venom is recommended. This involves a course of hospital administered injections with slowly increasing doses of bee venom following a careful program. Successful completion of such a treatment renders people more or less normal in their reaction to stings, though it is recommended that they should try to get stung once a week or so to keep their IgG immunity levels up. Unfortunately this treatment is not usually available on the NHS! Again the use of an antihistamine tablet before visiting the bees is recommended.

- For a fuller exposition, consult *"Medical Aspects of Beekeeping"* by Harry Riches MD FRCP published in 2000 by Northern Bee Books (ISBN 0–907908–94–2).