Honeybee: Diversity, Castes and Life Cycle

2

Sunita Yadav, Yogesh Kumar, and Babul Lal Jat

Contents

2.1 Introduction

Honeybees are insects that come under order Hymenoptera and family Apidae and showed complete metamorphosis. Honeybee species are characterized by particular functional traits that facilitate pollination services to a greater or lesser degree (Bluthgen and Klein 2011). Based on morphometric, behavioural and biogeographical studies, 26 subspecies have been identified (Ruttner 1988; Sheppard et al. 1997; Sheppard and Meixner 2003; Engel 2004; Arias and Sheppard 2005). *A. mellifera* occurs naturally over different geographical areas, extending from Scandinavia in the north to the Cape of Good Hope in the south and from Dakar in the west to Oman in the east. According to varying climatic conditions, the population is adapted to the particular geographical region (Ruttner et al. 1978). The colonies of *A. mellifera* are found from sea level to 1000 m above sea level in temperate zones and from sea level to 3700 m in the tropics, and they also survive in extreme hot and arid zone conditions of Oman (Dutton et al. 1981). *A. dorsata* is distributed in Pakistan, through the Indian subcontinent and Sri Lanka to Indonesia and parts of the Philippines in the east, and its distribution is similar to the dwarf honeybee. The rock bees from Nepal and the Himalayas have recently been reclassified as *Apis laboriosa*. However, it is not clear whether the rock honeybees of Sikkim and

S. Yadav (✉) • Y. Kumar • B.L. Jat
Department of Entomology, CCS Haryana Agricultural University, Hisar, Haryana, India
e-mail: sunitayadav10@rediffmail.com

Omkar (ed.), *Industrial Entomology*, DOI 10.1007/978-981-10-3304-9_2

Assam in northern India, western Yunnan Province in China and northern Burma should be classified as *A. dorsata* or as *A. laboriosa*. *A. florea* distribution is generally confined to warm areas, i.e. Pakistan, Iran, Oman, India and Sri Lanka. Its distribution almost ceases at altitude above 1500 m and is absent in north of the Himalayas. Frequently, it can be seen in tropical forest and cultivated areas. In contrast to all of the above, the distribution of *A. cerana* was found more in tropical, subtropical and temperate areas of Asia, occurring in the Indian subcontinent and Sri Lanka in the west, through South East Asia, to Indonesia and the Philippines in the east. For ages, colonies of the oriental honeybee, *A. cerana*, have provided mankind with honey and beeswax, as well as furnishing invaluable service in the pollination of agricultural crops. Among all the *Apis* species, only *A. cerana* and *A. mellifera* are domesticated by man because of their hidden nesting habit. Behavioural limitations of the dwarf and giant honeybees, particularly their practice of open-air nesting, prevent their being kept in man-made hives for reasonably long periods, while hiving colonies in specially constructed containers is essential in that it enables the colonies to be manipulated.

2.2 Honeybee Diversity

Honeybees comprise the genus *Apis* in the family Apidae, order Hymenoptera. The European honeybee is classified as *A. mellifera*, the Indian honeybee is *A. cerana*, the Koschevnikov's honeybee is *A. koschevnikovi*, the dwarf honeybee is *A. florea*, the andreniform dwarf honeybee is *A. andreniformis*, the giant honeybee is *A. dorsata* and the giant mountain honeybee is *A. laboriosa*. Three of these are native to Asia and one is native to the Euro-African region. All of these are similar in appearance, though there are differences in size and colour. All build vertical combs that are two cells thick. All bees feed on pollen and nectar and make nests with wax secreted from their bodies.

2.2.1 *Apis dorsata* Fabricius (Figs. 2.1 and 2.2)

This wild bee is also known as the giant or rock honeybee and found in Asia and occurs all over India, in wild state, at low altitude in the sub-mountain region (up to 1067 m above sea level) and in dry forests and wet regions as well as in the mangrove forests of Sundarbans (Beeson 1941). These bees build a single-comb, exposed nest measuring about 1.5–1.8 m from side to side and 0.6–1.2 m from top to bottom. However, the highest dimensions of a single comb are recorded to be of 2.1 × 1.2 × 0.3 m (Pant 1985). Nests are often seen hanging from branches of trees, roofs or ceilings and at higher altitudes, e.g. Shimla 2100 m (Singh 1962) and 3000 m (WOI 1988). Nest can occur singly or in groups in a single tree; such tree is called bee tree. The adult bees hang in curtains around the nest to control nest conditions. Due to its defensive behaviour, there is little potential for development in the management of either species, though there is often potential for improving the quality of the honey by using more care in processing. The giant honeybee is the most spectacular and ferocious of the four *Apis* species. The workers are the size of

Fig. 2.1 *Apis dorsata*

Fig. 2.2 *Apis dorsata* hive

a wasp and the queen is slightly bigger. The bees are a common sight on sweet shops in Indian markets and are seen sucking sugar syrup and also juices of grapes and other overripe fruits. In this process, they remain unmindful of their occasional brushing away with a piece of cloth. They rarely sting the shopkeeper and the customers unless accidentally crushed or trampled upon.

Distribution and Nesting Behaviour It is found all over India in the plains and in the hilly areas up to 2100 m above sea level. Geographical distribution extends to Pakistan, Sri Lanka, Malaysia, the Indo-China region, the Philippines, China and Indonesia. During summer, the colonies migrate to mountains up to the elevation of about 2100 m to avoid extreme heat or in search of flora. The colonies arrive in hills in March and April and return to plains in June/July before the monsoons. During migration, the swarms are known to make short halts. During winters, they are abundantly found in plains. The migration improves colony survival and provides several crops for honey in the areas during the year.

The nesting behaviour of this wild honeybee has been studied with much interest, and efforts have been made to hive it also. Under natural conditions, *A. dorsata* generally make their nests higher than 10 m, but some are seen at lesser heights, particularly in areas where there are only a limited number of tall trees. The honeybees build single combs on the projections of rocks or those of tall buildings in cities and more commonly on tall trees on the roadside, in gardens or in forests. Honeybee colonies prefer consistently old comb remnant sites for nest building and utilize them as an index and as visible signal to bee swarms for new colonization (Thakur 1991). More than a hundred colonies can be counted in the Taj Mahal gardens at Agra. Fletcher (1952) reported 156 colonies on a bee tree in southern India. They can make nests on any tree species including the thorny *Acacia catechu*, but they seem to show preference for the tall *Ficus* trees that have thick limbs wide apart, allowing free flight to the bees.

Comb Structure and Castes Giant honeybee colonies are known to exhibit a migratory lifestyle with several colony movements during an annual cycle (Koeniger and Koeniger 1980; Oldroyd et al. 2000; Woyke et al. 2000). Vertical single combs are built by these bees. The comb area can be up to 1 m^2. Individual combs can be very large, with reported dimensions of 1.5 m × 1 m (Oldroyd and Wongsiri 2006). The egg placement in the cells, the concentric arrangement of brood, the raising of queen cells, the issue of swarms, the communication by dances, etc. are broadly similar to *A. mellifera* and *A. cerana indica*. About 7000 bees would weigh 1 kg. Average tongue length is 6.68 mm. The queen is darker in colour than the workers and about one-fifth long as the workers and about 2 mm broader.

The combs made by this honeybee are large and semicircular, quite thick on top, where honey is stored and honey harvesters go for it. Combs are attached to the strong limbs of a tree, and the attachment is quite wide and strong to be able to carry the weight. On an average, there are 23,000 cells on the comb, constructed bilaterally on either side of the comb. The cells are hexagonal in shape and 5.35–5.64 mm in diameter and they slope upwards. The depth of a brood cell is 16 mm.

Brood and honey stores are in the same comb. In a comb, honey is stored on the top with thicker sides, and pollen is stored below, followed by the brood area. The queen cells are made at the lower end. In a colony, 80–90 % of the bees arrange themselves in a layer of 3–6 bees thick, and they are oriented in the same direction with their heads upwards and their wings half spread. This cover of bees is like a bag that touches the comb at the edges, leaving a hollow space of 1–2 cm between the comb surface and the cover of the bees. This space is used by the nurse bees to move around and feed the brood. At the lower end of the bag, there is a mouth open for the worker bees to enter and to come out. The field bees perform dances at the exposed portion of the comb on the vertical plane.

In a colony, the brood is reared in worker cells. Worker and drone cells are equal in size. Both giant honeybee species, *A. dorsata* and *A. laboriosa*, are unique in the genus *Apis* in that the hexagonal cells used for rearing drone and worker brood are the same size, albeit this is a debated point, i.e. Tan (2007) reports a statistically significant size difference between drone and worker cells; however, previous research reports no consistent difference (Oldroyd and Wongsiri 2006). The capping of the drone cells is raised, whereas those of the worker brood are flat. The queen cells are made on the lower rim of the comb. This honeybee like other *Apis* species also produces reproductive swarms. Once swarming starts, it may continue for some time, and a new swarm may be issued every 3–4 days. The new swarms generally settle at some distance in the area. A unique feature of this honeybee is that a nucleus colony may sprout out of the mother colony and settle at a distance of 1 m on the same limb of the tree. A new comb is built, and at first, the workers keep moving between the mother colony and the nucleus, but after a few days, the nucleus becomes independent. It appears this honeybee is capable of nocturnal orientation.

Behaviour The behaviour of the species is unpredictable and they will not live inside a hive. Generally, these bees show ferocious temperament and are provoked by slight disturbance. Worker bees attack in mass and follow the victim over long distances. Worker bees cover the comb like a curtain and orient upwards for insulation and protection. They are sensitive to smoke which is normally used by honey hunters.

In the normal working state of the colony, it is not at all aggressive. A strong wave of "shimmering" is passed every time they are disturbed by hand. It is reported that most of the small animals that might approach the colony as enemies are repelled by this shimmering.

They ignore the people who may walk or sit under the trees. The bees attack only when they are disturbed by a stone, stick or any other thing. The suspected enemy (quite often an innocent traveller) is then attacked in scores, within a radius of hundreds of yards of even up to 1 km. After stinging men, cattle and animals for hours, it takes them a long time, in fact an overnight, to calm down moderately. Even the next morning, some excited bees are seen scouting around. It appears that colony defence in the open is an evolutionary behaviour. During this state of excitement of the colony, many passers-by are stung by multiples of bees or by a cloud of bees, and the victim writhes on the ground in agony and even loses the presence of mind to call for help. In many cases near the colony, 80–100 stings per victim are a common occurrence. The very first step to be taken is to save the victim from shock and subsequent death, by administering antidotes, through regulated injections. In case a single alarmed bee makes a run, as many as 5000 bees may be alerted out of the curtain of bees. Only one bee has to sting, and the smell of isopentyl acetate released because of stinging will convey to the other bees where to locate the "enemy". The smell lasts for 10–15 min and within that time, the victim is at a great peril. The bees chase him menacingly, and the only escape for him is to decoy and hide behind a hedge, to lie on the ground with face downwards, to cover himself with a sheet of cloth or a blanket and to protect his naked body parts.

Honey-Gathering Behaviour The giant honeybee has a great economic value in India, as this species is a good honey gatherer. Honey is stored in the top half portion of the comb. It can, therefore, be harvested without destroying the colony by cutting the honey-storing portion of the comb. Honey yield is as high as 50–80 kg honey per colony, which can be obtained from a single comb. A sizable portion of honey produced in India comes from *A. dorsata* species.

Before the introduction of *A. mellifera*, it contributed 60–70 % to the honey crop and practically all the commercial wax (ghedda) in the country. In quality, honey is like the hive honey provided extraction is done properly. In Nepal and eastern and central India, it plays an important role in the economy and tribal life of the people. Those who have learnt the art of honey harvesting climb a tree or a rock with a bucket or a basket. A small fire and smoke is started underneath, and they reach the comb, cut out the thick top corner full of honey, pour it in a basket or a bucket and come down. When the bees migrate in the hot summer before the monsoon, the entire comb is brought down for wax. Among the tribes, that art is developed to varying degrees, and there is a wastage and unnecessary killing of the bees. From the cave paintings found in central India, it is evident that honey harvesting has been practised for thousands of years.

Foraging Behaviour Honeybees were found as predominant pollinators (85.23 %) in the seed production plot. Earlier, Sharma et al. (1974) reported that honeybees were the predominant pollinators (42.1 %) of cauliflower. Sinha and Chakrabarti (1980) reported that honeybees constituted 79, 82.4 and 83.3 %, respectively, in 3 consecutive years. Kakkar and Sharma (1991) observed that honeybees constituted 38.7 % on cauliflower bloom. The foraging efficiency of honeybees directly affects the crop production and productivity, and it depends on the availability of bee forage, conditions of the colony and foraging range of worker bees (Pudasaini and Bahadur 2014). Observations on the foraging behaviour of the species showed that their behaviour is similar to domesticated *Apis* species. But in contrast to domesticated bees, *A. dorsata* bees have been reported to forage during night also. Selvakumar et al. (2015) reported that among bees, *A. dorsata* (10.16) visited more flowers than *A. mellifera* (8.68), *A. c. indica* (7.16) and *A. florea* (4.86). Depending upon the flower structure, they act both as top and side workers. This species is very hard working and very efficient pollinator of crops in India. This honeybee is also common on *Brassica* crops, *Eruca sativa*, sunflower and cucurbits in Punjab, Haryana and Himachal Pradesh. Pudasaini and Bahadur (2014) reported that *A. dorsata* visited 9.33 and 15.83 flowers at 10:00 am and 2:00 pm of the day, respectively, with the peak foraging hours of around 1200–1400 h.

Seasonal Migration The migratory open-air nesting *A. dorsata* honeybee migrates at least twice a year (Deodikar et al. 1977; Koeniger and Koeniger 1980; Reddy 1983; Venkatesh and Reddy 1989; Underwood 1990; Dyer and Seely 1994; Kahono et al. 1999; Thapa et al. 2000; Lipiński 2001; Woyke et al. 2001; Liu et al. 2007). The same nesting sites are occupied year after year. Neumann et al. (2000) and Paar et al. (2000) genotyped the migrating *A. dorsata* bees and showed that the same swarms return to their natal nesting sites. The seasonal migration of *A. dorsata* is quite spectacular. As forage decreases towards the end of the season, colonies abandon their combs and migrate to lower elevations, establishing new nests there for the mass flowering of the monsoon season (Ahmad 1989; Dyer and Seeley 1994). They descend from the mountains to the plains of India after the monsoons or from the highlands to the coastal areas in South India and flourish on the winter flora of crops, trees and shrubs. They raise their brood and gather honey (some is harvested by man), and in the summer they are ready to migrate to altitudes less than 1500 m. It is almost certain that they perceive and forecast the oncoming events and prepare to move to safer areas before the crushing monsoons in southern, eastern and northern India.

With the coming of summer, the desert areas and the plains of northern India burn with heat. The atmospheric pressures fall and the dust storms are ready to whirl around in the countryside, and it appears the bees are set to avoid them, and hence they must migrate to safer areas to the mountainsides where there is thick vegetation cover. The way the mighty swarms move from their abodes on tall trees as if at a short notice, by some elaborate system, the scientific phenomenon is worth studying and recording further.

The migration of *A. dorsata* from the plains of Kalka and up into the valley reaching Kasauli is very interesting. Around 15th of May every year, overpowering humming sounds are heard almost all day, and groups of swarms of *A. dorsata* bees are seen coming up the valley almost following the contours of the terrain, from 5 to 30 m above the ground moving upwards and settling into the jungle up to 1500 m high. The swarms when they come are a sight to be seen. Many times a swarm arrives late in the day and stays overnight, settling on a low tree, and the next morning they are gone. This commotion goes on day after day for weeks. It seems that the migrating swarms somehow excite others on the way, and they make quick preparations (using up honey reserves) to move along. In the empty combs, hardly any honey is left behind since it is used up by the bees before leaving.

2.2.2 *Apis florea* Fabricius (Figs. 2.3 and 2.4)

This bee is also known as the dwarf or little honeybee and is found in Asia. Like *A. dorsata*, these bees build a single-comb, exposed nest. Nests are built around a twig of a shrub or a branch of a tree. They are the smallest honeybee species both in size of the body and the nest.

Distribution These are generally confined to warm climates. This species is found in the plains of India up to about 300 m above sea level. This species is distributed in India, Sri Lanka, Pakistan, the Indo-China region, Malaysia, the Philippines, Indonesia and up to Iran and Oman in the west. This is a wild bee, but attempts to keep it in specially designed hives have met with partial success in India. *A. florea* is highly migratory, but long-distance migrations are unknown. This honeybee also has a habit of nest shifting within short distances. The bees may shift within 2 months in dry season and within 5 months in the rainy season. When they shift, they carry away all the provisions, including wax. When disturbances cause them to

Fig. 2.3 *Apis florea*

Fig. 2.4 *Apis florea hive*

desert the comb, then they leave behind honey, brood and pollen stores. But the bees continue to return to old comb to take away comb wax, honey and pollen.

Comb Structure and Castes The little bee builds a single vertical comb nest, and the comb is constructed around the stem of a bush, branches of bushes, hedges, trees or a dried thick stick in the shaded places. The nesting location of *A. florea* is unique, not easily accessible to animals including mankind that could help avoid animals including human interferences and vehicular traffic. Accordingly, *A. florea* builds its colony at interior side away from the road. *A. florea* avails various plant species including human-built structures for nesting under shady places on the twigs/branches. Shady places help protect the colony members from bright light, strong winds and inclement weather conditions. Even though *A. florea* nests ranged between ground level and up to 50 ft, it preferred ground level to up to 15 ft height more (Vaudo et al. 2012; Woyke et al. 2001; Manunath 2008). Sometimes, the combs are constructed in a protected place in the hollow of a hedge, a stack of sticks or even a hollow in a building structure. At the top the nest encircles the strong stem so as to give it a good strength. The portion of the comb that encircles around the stem (or on the flat of ceiling in a building) is thick, but as the comb is built further down, it becomes thin in depth, although as broad as the upper portion. In the autumn, they move short distances to unshaded nesting sites. The adult bees hang in curtains around the nest to control nest conditions. In the same comb, brood is present in the lower section and the honey is found in the upper section. The comb is broad at the top and it serves as a landing place for the foragers.

The comb itself is less than 1 ft in length and contains about 14,000 cells. The size of all the three types of cells varies with geography and becomes smaller as we go from north to south. In a colony, there are about 6000 bees, and the queen lays 350 eggs per day in a brood area of 600 sq. cm. The worker brood cells are made on the flat surface in the middle of the comb. The comb is always covered by a curtain of bees. Drone cells are 1.5 times larger in diameter than worker cells and are found on the lower part of the comb. Queen cells are raised in spring and autumn at the bottom edge of the comb and are quite large. Compared to the other species of honeybees, its workers have a long life of 61.2 days, that is, 2.5 times that of an *A. mellifera* worker.

Since this honeybee shifts a lot, it would appear its biology is adapted to multiplication, swarming and dissolution of the colony with the purpose of reassembling under a new situation. During a short span of 2–5 months, the nest is built, brood is reared, honey is stored and 12–16 queen cells are built for further propagation. When the first virgin queen emerges, half the number of workers leaves along with the mother queen. Subsequently, the virgin queens mate and smaller swarms leave every few days. In the end, a handful of bees remain on the comb, and eventually they also swarm away or simply disperse, leaving the comb bare and deserted.

Behaviour These bees are very prone to swarming. They are gentle in temperament; however, they do sting when irritated. Colonies can be shifted to crops at blooming time for pollination. In areas of its distribution, it lives along with *A. cerana* and *A. dorsata*; the ratio of their size is 1.0:1.27:2.09, respectively. The ability to survive in a very hot and dry climate is its special trait, and it can live in deserts (50 °C) without any harm. The heat tolerance ability is further demonstrated by the fact that worker bee's daily activity starts at 18 °C and continues up to 40 °C. It is no wonder that this bee is a relentless visitor of flowers of crops, trees, shrubs and the annuals. Her small size restricts her to a shorter flight and hence she exploits the flowers intensively. In one study, on *Brassica* crops this bee constituted 73–74 % of the insect visitors observed. The swarms forming the new colonies generally settle at a distance of less than 100 m, after shifting their site a few times. Some swarms do go far but not more than a few hundred metres. It has been observed that if a queen is removed or it dies naturally, the workers build a queen cell by modifying a worker cell somewhere in the middle of the comb.

Honey-Gathering Behaviour Due to small size of its comb, *A. florea* is a poor honey yielder, and a comb yields 200–900 g of honey. The honey is thin in consistency. Honey hunters take away the whole comb and thus destroy large number of colonies. The honey produced by this species is believed to have special medicinal qualities, but there are no scientific studies to support this belief. The medicinal value, if any, must be attributed to the nectar of the plants in the locality that are available to other bee species also. *A. florea* honey fetches higher price in countries like Oman.

A. florea even though quite small in body size can be quite aggressive and resort to robbing the nests of *A. mellifera* which is much bigger in body size and greater in colony strength. Lately, some researches on this honeybee have also been conducted in Oman and in Iran showing interest in its preservation as a species.

Foraging Behaviour Foraging behaviour is similar to other bees and shows consistency in foraging on a single crop during visit. They are top workers. Abrol (2010) reported that the dwarf honeybee *A. florea* was the most abundant flower visitor and comprised more than 94 % of the total visitors. Commencement of flight activity occurred when a minimum threshold of environmental variables was exceeded, while the cessation was governed mainly by decline in light intensity and radiation. They do not forage at night as seen in *A. dorsata.* They can forage better on crops with small flowers or in umbelliferous crops. On average, *A. florea* visited 1.33 ± 0.26 and 6.17 ± 0.58 umbels and flowers/min, during different hours of the day.

2.2.3 *Apis mellifera* Linnaeus (Figs. 2.5 and 2.6)

This is a domesticated bee species, also known as European or Euro-African honeybee. These bees can be kept in hives, and methods have been devised to allow for a more rational utilization of their potential. The bee is similar in habits to the Indian honeybee in that it builds multiple combs parallel to each other with uniform bee space. Combs are built in hollows of trees, in walls or in shady places. It is with this species that a potential for beekeeping development exists.

Distribution It is native to Western Asia, Europe and Africa. This species is found all over Europe and spread to other continents during the last five centuries.

Fig. 2.5 *Apis mellifera*

Fig. 2.6 *Apis mellifera* hive

European races of the western hive bee have been introduced into most parts of the world, including America, Australia and Asia. *A. mellifera* is the most widespread of these species, occurring throughout Europe, Africa, Northern and Western Asia (e.g. Ponto-Caspian and as far east as the Tien Shan), the Levant, Caucasia and the Iranian Plateau (Ruttner 1988, 1992; Ruttner and Kauhausen 1985; Sheppard et al. 2003), as well as adventive in the Americas and Australia (Kerr 1957; Sheppard 1989; Engel 1999; Moritz et al. 2005). Now, it is found almost in every country. This bee has been studied intensely from both a strict biological and a beekeeping viewpoint. There are many well-recognized races and strains of *mellifera* which greatly differ in appearance.

Comb Structure and Castes This species of *Apis* normally build multi-comb nests in enclosed cavities. Tongue length varies from 5.5 to 7.2 mm. It has many desirable traits. It maintains a prolific queen, swarms less, has gentle temperament and is good honey gatherer. This race has achieved a great success in some states of India and has proved to be superior performer than *A. cerana*.

Races There is tremendous variation in this bee across its range, and at least 20 different subspecies or “races” are recognized, broadly divided into European and African groups. Several races of this bee are considered especially desirable for beekeeping. The western honeybee or European honeybee (*A. mellifera*) is a species of honeybee comprised of several subspecies or races. At least 29 subspecies of *A. mellifera* have been delineated on the basis of morphometry (Ruttner 1988; Engel 1999; Sheppard et al. 2003). These subspecies are now typically divided into four major groupings, supported by morphometric and genetic studies in addition to analyses of ecological, physiological and behavioural traits: group A, which includes subspecies throughout Africa; group M, which includes subspecies from

Western and Northern Europe; group C, which includes subspecies from Eastern Europe; and group O, which includes species from Turkey and the Middle East (Ruttner et al. 1978; Ruttner 1988; Garnery et al. 1992; Arias and Sheppard 1996; Franck et al. 2001; Miguel et al. 2011). There are many different races of *A. mellifera*, some tropical and others temperate.

African bees are termed as killer bees. They were imported into Brazil in an attempt to establish an industry in some of the tropical regions. Some of these bees accidentally escaped and became established. They have continued to expand their range in the tropical lowlands, and in most cases, they have actually replaced the existing European bees. The establishment of African bees in tropical America has caused a great disruption of the beekeeping industry. The African bee is noted for its defensiveness and unpredictability. These are characteristics considered undesirable from a beekeeper's point of view.

Behaviour They are gentle in temperament, but when irritated they do sting although workers die after stinging.

Honey-Gathering Behaviour Field honeybees collect flower nectar. On entering the hive with a full honey sac, which is an enlargement of the oesophagus, the field bee regurgitates the contents into the mouth of a young worker, called the house or nurse bee. The house bee deposits the nectar in a cell and carries out the tasks necessary to convert the nectar to honey. When the honey is fully ripened, the cell is sealed with an airtight wax capping. Both old and young workers are required to store the winter supplies of honey. In migratory beekeeping, it produces an average of 50–60 kg honey/year/hive. Yields of 100 kg/year or better are possible under optimum conditions.

Foraging Behaviour Foraging is a social enterprise (Seeley 1985) in which bees collect pollen, nectar, water and propolis from plants. The act of collecting all these is called foraging and the bee is a forager. Under normal colony conditions, the forager bees are workers with an age of over 21 days, at which time they shift to perform out-colony tasks including water, nectar, pollen or resin collection (Sharma 2014). Pollen is carried into the nest or hive on the hind legs of the field bees and placed directly in the cells. The pollen of a given load is derived mostly from plants of one species, which accounts for the honeybee's outstanding role as pollinator. The anticipation of the commencement of foraging is associated with an increased titre of juvenile hormone (JH) in foragers which is not affected by foraging experience but by diurnal variations (Elekonich et al. 2001). If it flew from one flower species to another, it would not be effective in the transfer of pollen, but by confining its visits on a given trip to the blossoms of a single species, it provides the cross-pollination required in many varieties of plants. Like *A. dorsata*, foraging behaviour depends upon the flower structure. Generally, the foraging skills and the number of forager workers increase with age (Dukas and Visscher 1994).

2.2.4 *Apis cerana* Fabricius (Figs. 2.7 and 2.8)

The eastern or Indian or Asian hive bee (*A. cerana*, synonym of *A. indica*) is native to Asia. Beekeeping is developed with this bee in different regions of Asia, since it can be easily hived in fabricated containers. There is a lot of variation in the eastern hive bee across its range, and little work has been done towards selecting more desirable strains from a beekeeping point of view. Techniques of beekeeping with this bee are similar to those used with the western hive bee, though the hives used are smaller.

Distribution This species had been the base of Indian beekeeping and found throughout India except the plains of North India. *A. cerana* is the Asiatic honeybee or the oriental honeybee because they are only found in Asia, from Iran in the east to Pakistan in the west and from Japan in the north to the Philippines in the south. Thus, *A. cerana* does not live only in tropical and subtropical areas of Asia but also in colder areas such as Siberia, Northern China and the high mountain area of the

Fig. 2.7 *Apis cerana*

Fig. 2.8 *Apis cerana hive*

Himalayan region (Koeniger 1976). It thrives up to 2500 m above sea level. In China and Japan, the indigenous domesticated *A. cerana* has now mostly been replaced by *A. mellifera* which was introduced some years ago.

In India, there was hardly any beekeeping with *A. cerana* in Punjab, Haryana and the plains of Uttar Pradesh, but *A. mellifera* is doing very well in these areas. The Indian race of the species is *A. c. indica*, and there are many distinct strains present in different geographical regions. It occurs naturally up to 46°N in Asia east of Iran and in the valleys of Hindukush and Himalayas up to 2000 or even 3000 m in the southern valleys of these mountain ranges.

Comb Structure and Castes Feral colonies of *A. cerana* are found in hollows of trees and holes in the rocks or the walls of houses. In the indigenous methods of beekeeping in India, the nesting situations are simulated, and bees are kept in log hives (Figs. 2.9) and in hollowed out house walls with entrance hole opening on the outside and window opening on the inside. Records of this method of beekeeping in Kashmir are available dating back 1470 A.D. In nature, a colony has 6–8 combs with 6000–7000 workers in subtropical areas and 10,000–20,000 in temperate areas like Japan.

The diameter of a worker cell and worker bee varies a great deal in various parts of Asia. The cell size is 4.87 mm in Peshawar, 4.78 in Japan, 4.67 in Peking, 4.25 in the plains of India and Thailand and 4.2 in Sri Lanka. This honeybee has the habit of gnawing wax of old cells down to the middle sheets. Thus, wax debris accumulates at the bottom and provides medium for the development of wax moth. The standard Langstroth hives by itself are not suited for this bee, but if the bee space in between the combs and the cell size is suitably altered, the hive will be accepted. For the tropical South India, a smaller hive containing 6–8 movable frames has been

Fig. 2.9 *Apis cerana* log hive

devised, commonly known as the villager hive; it has many variations in the dimensions of frames and hives.

The drone cells of *A. cerana* have characteristic holes like pores in the capping which is not the case in *A. mellifera.* The caste system, the colony structure, the parallel comb arrangement and the biology of the two species are very similar, but the fanning position at the hive entrance is the opposite; in *A. cerana*, the workers keep their head away from the entrance, whereas in *A. mellifera* the workers keep their head directed towards the entrance. The sequence of functions by the workers is the same in the two, but *A. cerana* workers perform the various functions a little early in life, e.g. cell cleaning starts before the third day; brood care, pressing the pollen in cells and comb construction start on the third day; development of pharyngeal glands starts between the 4^{th} and 16^{th} day; the wax glands start functioning on the third day, but the maximum secretion is between the 12^{th} and 16^{th} day; and the orientation flights are between the 7^{th} and 11^{th} day.

Behaviour *A. cerana* is a bee with gentle temperament and it responds to smoking. It is frugal in habits but lack of flora is quickly reflected into absconding. It also has a strong tendency for swarming; a colony may issue up to 5–6 swarms in a year. Management and manipulation practices to prevent and control swarming also do not always work. Due to incessant swarming, ravages of bee enemies, lack of honey flora and resultant absconding, one comes across a large number of weak colonies. It is poor propolizer, and practically no propolis (bee glue) is brought to the nest for reinforcing the combs or sealing the cracks, etc.; therefore, wax moth does considerable damage.

Although yields are considerably lower than with the western hive bee, this bee has the advantage of being well adapted to the area. It is more resistant to some of the disease and pest problems found in the area. Therefore, it is better able to survive under the minimal management conditions that often characterize beekeeping at the small-farmer level.

In recent years, there has been an effort in Asia to replace the eastern honeybee with European races of the western honeybee. This has been successful only in temperate regions and only for large-scale, capital-intensive operations where the technology is available to control disease and parasite problems of the European races. In any small-scale beekeeping development effort, the existing bee resource of the area should be used. Importing bees for such a project is far riskier than it is worth. Imported bees often are not adapted to the areas into which they are introduced. Importing bees also risks the introduction of exotic bee diseases and parasites.

As compared with the western honeybee, *A. cerana* bees are more excitable when disturbed and are prone to sting more readily, particularly when the weather outside is chilly. The smell of body sweat or a perfume also excites them. When a hive is knocked, the bees inside make a hissing sound produced by quick movements of wings. The same sound is produced when one blows at an exposed frame;

the bees move away exposing the cells which can then be examined. When the bees are attacked by enemies like a wasp or a large black ant, they raise the abdomen and collectively make violent lateral shakings. The hissing sound and the shaking movements frighten the enemies. If a giant wasp (*Vespa mandarinia*) comes to the colony as a predator, he has to face the wall of bees that may ball around him and even kill him without suffering a single casualty.

A. cerana has the habit of absconding during the dearth period, and the attack of enemies like wasps and wax moth further aggravates absconding behaviour. In order to check absconding, the colonies should be shifted to areas where there is good nectar flow and there are comparatively fewer enemies. Competition from other honeybees (*A. mellifera*) may also cause commotion and absconding.

Mated *A. mellifera* queens are accepted by *A. cerana* workers, who raise the brood, and the workers of both the species live together for some time and eventually *A. cerana* die out of old age and the colony becomes pure *A. mellifera*. The reverse queen introduction is not likely to be a success owing to pheromone differences of the queens; chemically, their pheromones are alike, but *A. cerana* lacks a component, whereas that of *A. mellifera* has a broader spectrum. Queen rearing, queen emergence, mating and reproductive swarming are similar in the two species. In *A. cerana*, an average of nine queen cells has been observed in the swarming season.

Mating Behaviour Reproductive swarming is a regular feature of *A. cerana*, and it starts when the colony strength is around 20,000 bees. The drones fly between 1115 and 1515 h, and the maximum number comes out between 1215 and 1415 h. The flight activity of drones and queens of *A. cerana* (Ruttner et al. 1972) was observed in an isolated place; eight queens mated, three of them on two flights. Successful mating flights were longer than those of *A. mellifera* (average of 30.8 min). In body development, *A. cerana* drones are smaller, and they contain around 1 million spermatozoa as compared with 10–11 million in *A. mellifera*. The queen of *A. cerana* on emergence goes out for mating flight after 4 days, between 1330 and 1530 h, and most probably multiple mating (8–10) takes places until the spermatheca of the queen is filled with 3.5 million spermatozoa. The queen starts laying eggs within 2–3 days after mating.

As in other *Apis* species, drones in *A. cerana* develop from unfertilized eggs and the workers and queens from fertilized eggs. On the loss of a queen, the colony becomes a laying worker, and from the unfertilized eggs, drones develop and ultimately the colony perishes. The cell size on the foundation sheets is smaller suiting this species.

Honey-Gathering Behaviour Honey yields of up to 15–20 kg/year are obtained in some areas, but the average is much lower. Because of small size, short foraging distance, absconding, swarming, etc., this species is a low honey yielder. On an average, a colony yields 3–5 kg of honey per year in plains, but the yields are as high as 20–25 kg in Kashmir. The selective breeding does help in improving the desirable traits but of little practical value because of no control on parentage.

Foraging Behaviour These bees have short foraging distance but, efficient pollinators of different crops of coastal and hilly areas. These are top workers. In its natural area of distribution, *A. cerana* is a common visitor of a number of crops like *Brassica*, clovers, sunflower, *Eucalyptus*, pome fruits, coconut and other palms, rubber, etc. It is a gatherer of honey on most of these plants and is an important pollinator of pome fruits. *A. cerana* bees started their foraging activities early in the morning (06.14 ± 0.004) and ceased late in the evening (17.28 ± 0.011) (Singh 2008). The total duration of foraging activity was 1000 h and the average duration of foraging trip was 4.5 ± 0.14 min. Two peaks of foraging activities were observed between 0830 and 1030 (peak I) and 1130 and 1330 (peak II). The peak I period was the main foraging period, and peak II was the second foraging period; both were very useful from the pollination point of view.

As a honey gatherer and, possibly, an exploiter of flora, *A. cerana* seems to be frugal in her behaviour; she can sustain herself at lower colony strength, fewer resources and lower colony activity as compared with *A. mellifera.* It starts its daily activity at temperatures as low as 6–8 °C in winter, whereas *A. mellifera* is active at warmer temperatures with stronger colony strength. A further distinction of behaviour is that *A. cerana* visits a greater variety of cultivated and wild plants as in a natural habitat of a forest area, while *A. mellifera* sticks to fewer but rich resources.

Races In India, based on morphological features, two "races" of *A. cerana* are identified: a black "hill" morph that is often said to live at higher elevation and a yellow "plain" morph found at lower elevations (Kapil 1956; Narayanan et al. 1960a, b). The intra-specific classification of the Asiatic honeybee species, *A. cerana*, is in a state of flux and uncertainty (Hepburn et al. 2001). Studies carried out by the International Centre for Integrated Mountain Development (ICIMOD) reveal that *A. cerana* populations can be divided into three subspecies, namely, *Apis cerana cerana*, *Apis cerana himalaya* and *Apis cerana indica*. Of these, *A. cerana cerana* is distributed over the north-west Himalayas in India, North-West Frontier Province of Pakistan and Jumla region of Nepal. *A. cerana himalaya* is found in hills of Nepal, Uttar Pradesh, the north-east Himalayas and Bhutan; *A. cerana indica* is found in the plain areas and foothills of the region. However, based on morphometric observations, four major races of this honeybee have been described. *A. c. indica* is the smallest and is distributed in South India, Sri Lanka, Bangladesh, Burma, Malaysia, Thailand, Vietnam, Indonesia and the Philippines. The standard size *A. c. himalaya* is distributed in Afghanistan, Jammu and Kashmir, North India, China and North Vietnam. *A. cerana cerana* is distributed in most parts of China. There is a large size race *A. cerana japonica* that is distributed in Korea and Japan.

2.2.5 *Apis koschevnikovi*

Newly identified honeybee species is very similar to *A. cerana*. This species was first described by Buttel-Reepen, who dedicated it to Koschevnikov, a nineteenth-century pioneer of honeybee morphology (Gupta 2014). The species was described again by Maa in 1953, this time with the name *Apis vechti*. It was finally rediscovered by Tingek et al. in 1988. Its other name is the red bee (this species was named for a short period as *Apis vechti*). It also nests in natural cavities and builds multiple parallel combs. It has been reported from only some parts of Indonesia.

2.2.6 *Apis andreniformis* (Fig. 2.10)

Another small honeybee species is recently reported and is similar to *A. florea* in many ways. The dwarf honeybees, *A. andreniformis* and *A. florea*, are sister species with a partially sympatric distribution in southern Asia. It also builds a single comb in the open like the latter and is absent from colder climates where the more widespread multiple-comb, cavity-dwelling honeybee species occur. Although their propensity for and frequency of swarming and migration vary regionally, it is almost always associated with the sequence: rainfall > flowering > swarming or migration (Hepburn and Radloff 2011). It has been reported from Thailand, China and Malaysia. The dwarf honeybee, *A. andreniformis*, extends from the eastern foothills of the Himalayas eastward to Indochina, Sundaland and the Philippines.

2.2.7 *Apis laboriosa* (Fig. 2.11)

This species has also been identified recently. It is similar to giant honeybee in many ways. The giant honeybees of Nepal and the Himalayas have recently been reclassified as *A. laboriosa* (Gupta 2014). Although minor variations in anatomical, physiological and behavioural characteristics exist among the different geographical races of the giant honeybees, they are essentially similar in all their major biological

Fig. 2.10 *Apis andreniformis* (Source: Nicolas Vereecken, https://www.flickr.com/photos/nico_bees_wasps/5592188371)

Fig. 2.11 *Apis laboriosa* (Source: https://www.pinterest.com)

attributes. It also builds a single comb in the open. Its presence has been reported from Western China, parts of the Himalayas, Nepal, Bhutan, Tibet and India.

It is called as the largest honeybee of the world and distributed in Nepal, Bhutan, Sikkim and Yunnan between altitudes of 1200 and 1400 m. It is distinctly larger than the common *A. dorsata* and remains active at comparatively lower temperatures and greater heights. It has exposed combs, and in its area of distribution, the temperatures range between 10° and −5 °C. The dense coat of long dark body hair appears to have good survival value.

2.3 Honeybee Castes, Colony Organization and Life Cycle (Figs. 2.12 and 2.13)

The honeybee is a social insect with three different types of individuals or castes in the colony: queens, drones and workers. Each caste has its special function in the colony. The workers are undeveloped females, the drones are known as males and the queen is the fully developed female. The queen's job is to lay eggs, as many as several hundreds in a day. These larvae develop into drones, workers or new queens, depending on how the workers treat them.

All young larvae of less than 2 days are fed with royal jelly by the massive provisioning scheme. The different feeding schemes determine the caste of the adult bee. Thus, any female egg or larva less than 2 days old has the potential to become either a queen or a worker. Each caste has a different developmental time and thus reared in a distinct type of cell. In this chapter these three castes, their cells and functions are discussed in detail.

Queen Bee The queen, a true mother bee, is the only female that is completely developed sexually. This is a result of a total diet of royal jelly during a developmental period. She is distinguished by her long, slender appearance, due to the full development of the ovaries in her abdomen. In the colony, she is found in the area of the brood nest.

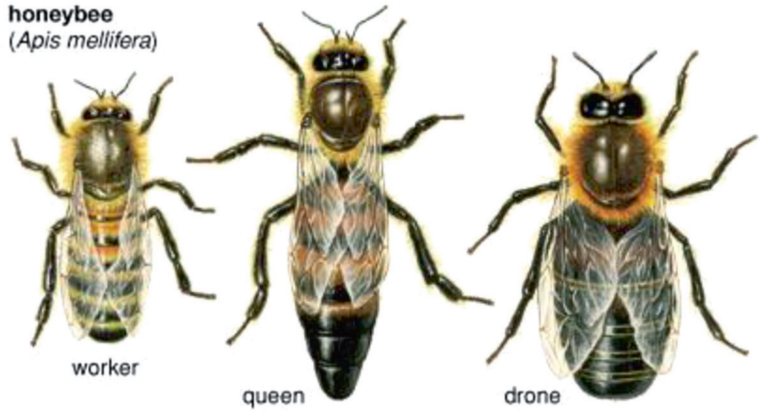

Fig. 2.12 Honeybee castes © 2006 Encyclopædia Britannica, Inc.

Morphological Features Either she is longer than a drone or worker, being over seven-eighths of an inch long and has a tapering abdomen. The queen's tongue is short, her jaws weak, eyes like the workers and wings short, hardly more than half the length of the abdomen. She has no pollen baskets, but possesses a sting without barbs that resembles that of the bumblebee, in being curved, yet, she seldom makes use of it.

Cell Shape The queen is reared in a specially constructed royal or queen cell. Queen cells appear similar to peanut shells that hang from the surface of the comb. They can be located along the edges of the comb or within the comb area. The colony constructs queen cells when there is a need to rear queens, though cells are sometimes started and then abandoned. These are called false queen cups.

Feeding The developing queen larva is always surrounded by royal jelly, a special, highly nutritious food produced by head glands of the workers. This feeding scheme, called massive provisioning, is unique to the queen and continues throughout her entire developmental period.

Developmental Period The developmental time of the queen, 16 days, is the shortest. The queen, like the workers, is developed from an impregnated egg, which comes from a fertile queen. The eggs are placed in queen cells, which are usually built on the edge of or around an opening in the comb and extend either vertically or diagonally downwards. These resemble a peanut in form and size. The eggs are placed in these cells, either by the worker bees, which transfer them from the worker cells, or else by the queen. The queen may be developed from an egg or from a worker larva less than 3 days old, which will then be transferred from a worker cell to a queen cell. The development of the queen is much the same as that of a worker, though she is fed richer and more quantities of food, called royal jelly. The condi-

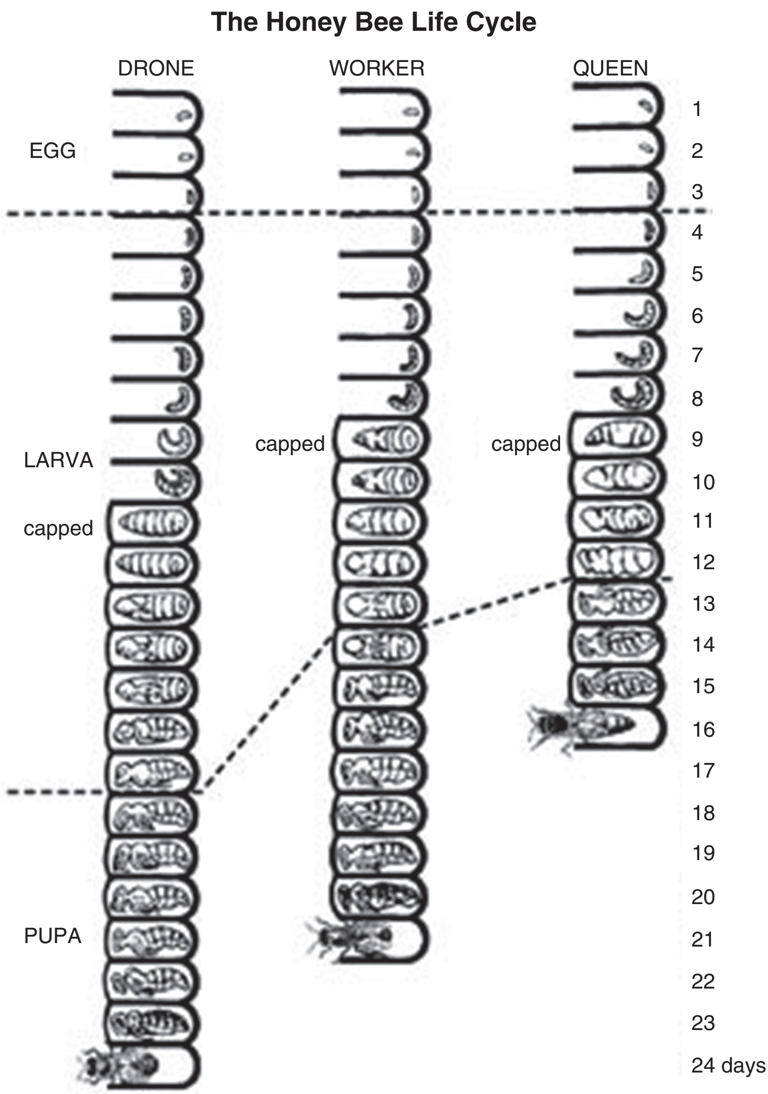

Fig. 2.13 Life cycle of honeybees (Source: https://www.pinterest.com)

tions which usually lead to the building of the queen cells are loss of queen, inability of queen to lay fertile eggs and too great numbers of bees or too little room in the hive, which is likely to be true in times of great honey secretion.

Mating Approximately, 5 days after emerging from her cell, if the day is pleasant, the virgin queen begins to take a series of mating flights, and otherwise she will wait for the first pleasant day for this purpose. She takes a number of such flights over a period of 2–3 days and may mate with ten or more different drones. The sperm is stored in a special organ, the spermatheca, and the queen never mates again after this period.

If the queen is observed upon her return from her wedding tour, it may be easily determined whether she has been successful. If she has been successful, she will bear the organ of the drone suspended to her body. If the queen lays any eggs before meeting the drone, or if for any cause she fails to meet the drone, the eggs will only produce drone bees.

Egg Laying and Behaviour About 5 days after taking her mating flights, the queen begins to lay eggs. During favourable periods, a good queen can lay more than 1500 eggs per day. Factors which affect egg laying are the weather, the nectar and pollen flows, the size of the queen and the condition of the colony. The number of eggs laid varies with the annual cycle as available resources of nectar and pollen vary. Large amounts of incoming resources stimulate workers to give the queen more food, which in turn stimulates her to lay more eggs.

Several of the queen's glands produce a complex of compounds called the queen substance. It is distributed throughout the colony by workers that care for the queen and pass it on to other workers. The queen substance is a combination of pheromones, chemical compounds that serve to control the behaviour of other individuals of the same species. Pheromones produced by the queen and by the other individuals of the colony serve to harmonize colony behaviour.

Number and Function Normally, there is only one queen per colony, though sometimes two queens are present when the old queen is being superseded. The function of the queen is simply to lay eggs and thus keep the colony populous; and this she does with an energy that is startling. A good queen in her best state will lay 1500 eggs a day.

The queen controls the sex of her offspring. When an egg passes from her ovary to her oviduct, the queen determines whether the egg is fertilized with sperm from the spermatheca. A fertilized egg develops into a female honeybee, either worker or queen, and an unfertilized egg becomes a male honeybee or drone.

Longevity The queen, when considered in relation to the other inhabitants of the colony, possesses a surprising longevity. It can live for up to 4 years, but in the tropics, where the yearly laying period is longer, the queen does not live as long. Depending upon their vigour and excellence, older queens either cease to be fertile or else become impotent to lay drone eggs, the spermatheca having become emptied of the seminal fluid. In such cases, the workers usually supersede the queen, that is, they destroy the old queen and start queen cells for the purpose of rearing young, fertile and vigorous queens.

Older queens do not have the laying capacity of younger queens; therefore, young, vigorous queens are preferred by beekeepers in intensive beekeeping; queens are replaced after every year.

Worker Bee Workers are females that are not fully developed sexually. They do the work of the colony and maintain it in good condition. Workers have special structures and organs which are associated with the duties they perform.

Morphological Features They are the smallest members of the colony, measuring a little more than one-half inch in length. They also possess peculiarities of structure that at once distinguish them from both the queen and drones. Their tongues are almost twice as long as in either the drone or queen, their jaws are much stronger and their wings attain the extremity of the body. The last joints of the posterior legs, known as the tibia and tarsi, are hollowed out to form pollen baskets. The presence of pollen baskets differs them from both the drones and the queen. The eyes are smaller than those of the drone but do not differ with the eyes of the queen.

The workers also possess a natural weapon of defence, the sting, which they use when the occasion requires, and usually die after stinging. The mechanism of this organ is very interesting. At its base is a double gland, which secretes the poison which, when secreted, is poured into an ample poison sack, which is as large as a flax seed. The sting proper is an organ, consisting of three sharp spears, very smooth and of exquisite polish, which lie side by side and make up the sting as seen by the naked eye. The central lancet is hollow, a little shorter than the others are. The central opening connects with the poison sack, so that all the poison passes through this part of the sting. The sidepieces are marvellously sharp, and each barbed at the end with teeth, of which seven are prominent and which extend out and back like the barb of a fishhook, so that the sting cannot be withdrawn when once fairly used and with its loss the bee's life is sacrificed. These sidepieces are worked alternately by small muscles at the base of the sting, and when fairly inserted the poison is intruded through the central piece. The workers also possess a honey stomach or crop, in which honey is carried to the hive.

Cell Shape Workers are reared in the same type of cell that is used to store honey and pollen. This type of cell makes up the majority of the comb in the colony. The capping on sealed worker cells is opaque and flat.

The size of the cells of naturally built (i.e. without embossed foundation) worker comb is useful for distinguishing between species and some races of *Apis* commonly kept in hives. The distance across ten cells of comb built by the eastern hive bee (*A. cerana*) in the Philippines averages 4.1 cm, and in southern India, the distance is 4.3–4.4 cm. The African races of the western hive bee build comb with measurements of 4.7–4.9 cm across ten cells, while the distance in comb constructed by common European races is 5.2–5.6 cm.

Feeding Worker bees are raised in the multipurpose, horizontally arranged cells of the comb. Future workers receive royal jelly only during the first 3 days, compared to future queens, who are fed royal jelly throughout their larval life. This difference accounts for the great variation in anatomy and function between adult workers and queens.

After the third day, worker larvae are gradually switched to a progressive feeding scheme where they are fed with a mixture of royal jelly, honey and pollen. With progressive feeding, the larvae are fed periodically; thus, food is not always available to them.

Pollen is used to feed older brood and is eaten in large quantities by nurse bees that are producing royal jelly from the head glands. It is the protein, vitamin and mineral component in the bee diet.

Developmental Period The adult worker emerges from the cell 21 days after the egg is laid. The workers always hatch from an impregnated egg, which can only come from a fertile queen and is always laid in the small horizontal cells. The eggs are in the form of a short, slightly curved cylinder and are fastened by one end to the bottom of the cell. They can be easily seen by holding the comb so that the light will shine into the cells. The eggs hatch in about 4 days.

The larva is white and footless and lies coiled up, floating in a whitish fluid previously placed in the cell. This food is composed of pollen and honey and is all consumed by the larva. In about 5 days, the cell is capped over by the bees. The cap is composed of pollen and wax, so that it is darker, more porous and more easily broken than the honey caps. It is also more convex. The larva, now full grown, commences to surround itself with a thin cocoon made of fine silk and in 3 days assumes the pupa state, when it is called a nymph. It now looks like the imago of fully developed bee, except that the legs, wings and tongue are folded on the breast, and the insect is now colourless. Upon the 21st day, the bee emerges from the cell.

Number and Function These are the most numerous individuals of the hive that make up about 98 % of the colony. Their number varies from 20,000 to 40,000 in every good colony. In a strong colony, maximum number of bees present on one side of the hive is 2000.

The tasks that the adult workers perform change with their age (Table 2.1). This is correlated with the physiological development of various glands. The function of the worker bees is to do all the manual labour of the hive. They secrete the wax, which forms in small pellets beneath the abdomen, build the comb, feed the young larvae and cap the cells, whether they may be brood or honey cells. This work is done by the younger bees. The older bees gather the honey; collect the pollen (beebread); bring in the propolis (bee glue), which is used to close up openings as a cement; supply the hive with water; defend the hive from all improper intrusion; destroy drones when their day of grace is past; kill and arrange for replacing

Table 2.1 Schedule of a worker bee in the hive

Days after emergence	Task
1–2	Clean cells and warm the brood nest
3–5	Feed older larvae with honey and pollen
6–10	Feed younger larvae with products of the head glands
11–18	Ripen nectar, produce wax and construct comb
19–21	Guard and ventilate the hive, take exercise and orientation flights to learn to fly and locate the hive
22+	Forage for nectar, pollen, water or propolis

worthless queens; and lead forth a portion of the bees when the conditions impel them to swarm. Pollen is collected just above the brood by all the honeybee species followed by honey on top of the frame. However, this scheme of work division is not absolutely fixed; workers can change tasks to meet the needs of the colony.

Longevity The life span of worker adults varies greatly with the time of year, but they never attain a great age. During periods when the colony is relatively inactive (dearth periods), workers may live 3 months or more, but when the colony is active, few workers live for as long as 6 weeks. During these active periods, about 3 weeks are spent as a hive bee and the remainder as a forager. In some cases, those reared in autumn may live for 9 months, while those bred in spring will wear out in 3 months. The life span of workers of tropical races of the western hive bee and the eastern hive bee is shorter. Their longevity depends upon their activity and hence upon the time of year in which they live.

Drone Bee Drones, the males of the colony, are produced from unfertilized eggs. The queen can control whether or not the egg is fertilized as she lays it. The body of the drone is larger than that of the worker or queen. The eyes are large and cover practically the whole head. The end of the abdomen is blunt and is covered with a tuft of small hairs. Drones cannot sting. As the sting is a modified structure of the female genitalia, drones do not have stings. They also do not have any of the structures necessary to collect nectar and pollen.

Morphological Features The male bees are only found in the hive from October until March, when there will be a few hundred, though the number may be controlled by the apiarist and should be greatly reduced. These are longer than the workers, being nearly of an inch in length and more bulky than either the queen or workers. Their flight is heavy, and they may be known by their deep, low hum. Their tongue is short, jaws weak and their posterior portion destitute of pollen baskets. The eyes meet above and are very prominent. The drones, too, have no defence organ, the sting being absent.

Cell Shape Drones are reared in cells of the same shape as worker cells only larger. Drone cells are sealed with dome-shaped capping. The capping of the drone cells is very convex and protrudes beyond the worker and darker in colour. Both drone and worker brood cells are very readily distinguished from honey cells.

Feeding Worker bees mix the honey with pollen and feed drone larvae. Future drones receive royal jelly for the first 3 days. After that, they are shifted to progressive feeding as discussed in worker feeding.

Developmental Period The developmental period of drones is 23 days. The male bees come from unfertilized eggs. These eggs may come from an unfertilized queen, from a fertile worker or from a fertilized queen, which may voluntarily prevent fertilization. Such eggs are placed in the larger horizontal cells in the same manner as the worker eggs are placed in the smaller cells. The development of the drones from egg to larva, to pupa and to imago is essentially like that of the workers, though they do not come forth till the 24th day from the laying of the egg. The difference of temperature and other conditions may slightly advance or retard the development of any brood in the different stages. The drones, like other bee castes, appear as grey, soft and unsophisticated when they first emerge from the cells.

Number and Function A strong colony can have about 300 drones. The longevity of the male bee is about 6 months. However, during periods when resources are scarce, the workers run the drones out of the colony. They die as they cannot fend for themselves. The sole function of the drones is to fertilize the queen. The mating of honeybees takes place in the air, away from the colony. When the weather is good (warm shiny day), mature drones leave the colony during the afternoon and congregate in certain areas where they wait for virgin queens to fly. After mating, the drone organs adhere to the queen, and their abstraction is fatal to the life of the drone. They die after mating. They have no sting, do not carry pollen and are unable to produce wax.

Other drones sometimes return to colonies that have a virgin queen. Such colonies will accept drones from other colonies and will tolerate a large drone population while the queen is a virgin. However, after a queen mates, the workers run many of the drones out of the colony.

The following table (Table 2.2) summarizes the developmental periods, starting at the time the egg is laid. Depending on the type (species and/or race) of honeybee, the weather conditions or the time of year, the figures may vary a day or so.

Table 2.2 Developmental periods of honeybee castes

Developmental period (days)	Worker	Queen	Drone
Egg hatches after	3	3	3
Cell is sealed after	9	8	10
Adult emerges after	21	16	24

Table 2.3 Organs, their location and function in worker bee

Structure of organ	Location	Function
Head glands	Front of the head	Produce brood food and royal jelly
Wax glands	Under the abdomen	Produce wax
Odour glands	Near the upper tip of the abdomen	Produce scent to orientate bees when the colony is disturbed
Sting and associated glands	Tip of the abdomen	Defend the colony
Long tongue	Head	Gathers nectar
Honey stomach	Enlarged area of the oesophagus	Carries nectar and water
Pollen comb, press and basket	Hind legs	Comb pollen from the body, press it into pellets and carry it to hive. Also used to carry propolis

Worker bee possesses different organs/glands to perform various functions. These are summarized in the following (Table 2.3).

Difference Between Eggs of Normal and Laying Workers When a colony has become queenless and there are no young larvae or female eggs from which to rear a new queen, laying workers can develop. The ovaries of some workers in the colony develop because of the absence of queen substance, and they start to lay eggs. Since workers do not have the body structure or behaviour necessary to be fertilized, all of the eggs are unfertilized and thus produce drones. Laying workers can be suspected in a colony if there are an excessive number of drones present. Close examination of brood comb can verify this. Worker cells that contain drone brood (i.e. worker cells capped with a domed cap) and cells that contain a number of eggs of varying sizes laid in a haphazard fashion confirm the presence of laying workers. A good queen lays only one egg per cell which is placed in the centre of the base of the cell.

2.4 Conclusions

Honeybees are one of the most fascinating organisms across phyla. Their usefulness to the human race can in no way be overestimated. Other than contributing directly to human well-being by producing a wide variety of products, honeybees are also responsible for enhancing the agricultural production through their pollination services. Honeybees are also a model system for understanding social behaviour, communication as well as extreme industriousness.

References

Abrol DP (2010) Foraging behaviour of *Apis florea* F., an important pollinator of *Allium cepa* L. J. Apic Resi 49(4):318–325

Ahmad R (1989) A note on the migration of *Apis dorsata* in the Andaman and Nicobar Islands. Bee Wrld 70:62–65

Arias MC, Sheppard WS (1996) Molecular phylogenetics of Honeybee subspecies (*Apis mellifera* L.) inferred from mitochondrial DNA sequence. Mol Phylogenet Evol 5:557–566

Arias MC, Sheppard WS (2005) Phylogenetic relationships of honey bees Hymenoptera: *Apinae: Apini* inferred from nuclear and mitochondrial DNA sequence data. Mol Phylogenet Evol 37:25–35

Beeson CFC (1941) Book: The ecology and control of the forest insects of India and the neighbouring countries

Bluthgen N, Klein AM (2011) Functional complementarity and specialization: the role of biodiversity in plant–pollinator interactions. Basic Appl Ecol 12:282–291

Deodikar GB, Ghatge AL, Phadke RP, Mahindre DB, Kshirsagar KK, Muvel KS, Thakar SS (1977) Nesting behaviour of Indian honeybees III. Nesting behaviour of *Apis dorsata* Fab. Indian Bee J 39:1–12

Dukas R, Visscher PK (1994) Lifetime learning by foraging honey bees. Animal Behaviour 48:1007–1012

Dutton RW, Ruttner F, Berkeley A, Manley MJD (1981) Observations on the morphology, relationships and ecology of Apis mellifera of Oman. J Apic Res 20:201–214

Dyer FC, Seeley TD (1994) Colony migration in the tropical honeybee, *Apis dorsata* F. (Hymenoptera: Apidae). Insect Soc 41:129–140

Elekonich MM, Schulz DJ, Bloch G, Robinson GE (2001) Juvenile hormone levels in honey bee (*Apis mellifera* L.) foragers: foraging experience and diurnal variation. J Insect Physiol 47:1119–1125

Engel MS (1999) The taxonomy of recent and fossil honeybees (Hymenoptera: Apidae; Apis). J Hymen Res 8(2):165–196

Engel MS (2004) Geological history of the bees (Hymenoptera: Apoidea). Revista de Tecnologia e Ambiente 10(2):9–33

Fletcher L (1952) Bee Craft 34(9):139–140

Franck P, Garnery L, Loiseau A, Oldroyd BP, Hepburn HR, Solignac M et al (2001) Genetic diversity of the honeybee in Africa: microsatellite and mitochondrial data. Heredity 86:420–430

Garnery L, Cornuet JM, Solignac M (1992) Evolutionary history of the Honeybee *Apis mellifera* inferred from mitochondrial DNA analysis. Mol Ecol 1:145–154

Gupta RK (2014) Taxonomy and distribution of different honeybee species (Eds) Beekeeping for Poverty Alleviation and Livelihood Security, pp 63–101

Hepburn HR, Radloff SE (2011) Honeybees of Asia. Springer, Berlin, xii + 669 pp

Hepburn HR, Smith DR, Radloff SE, Otis GW (2001) Infraspecific categories of *Apis cerana*: morphometric, allozymal and mtDNA diversity. Apidologie 32:3–23

Kahono S, Nakamura K, Amir M (1999) Seasonal migration and colony behavior of the tropical honeybee *Apis dorsata* F. (Hymenoptera: Apidae). Treubia 31:283–297

Kakkar KL, Sharma PL (1991) Studies on the role of honeybee, *Apis cerana indica* F. in the pollination of cauliflower, *Brassica oleracea var. botrytis*. Indian J Ent 53:66–69

Kapil RP (1956) Variation in the biometric characters of the Indian honeybee *Apis cerana indica*. Indian J Ent 28:440–457

Kerr WE (1957) Introdução de abelhas africanas no Brasil. Brasil Apicola 3:211–213

Koeniger N (1976) Interspecific competition between *Apis florea* and *Apis mellifera* in the tropics. Bee Wrld 57:110–112

Koeniger N, Koeniger G (1980) Observations and experiments on migration and dance communication of *Apis dorsata* in Sri Lanka. J Apic Res 19:21–34

Lipinski Z (2001) Essence and mechanism of nest abandonment by honeybees swarms. Blenam, Olsztyn, p 291
Liu F, Roubik DW, He D, Li J (2007) Old comb for nesting site recognition by *Apis dorsata* Field experiments in China. J Insect Sci 54:424–426
Maa T (1953) An inquiry into the systematics of the tribus Apidini or honeybees (Hyn.). Treub 21(3):525–640
Manjunath MG (2008) Studies on nesting behaviour of giant honeybee, *Apis dorsata* F. in Mysore, Karnataka. M. Phil, Dissertation, pp 1–103
Miguel I, Baylac M, Iriondo M, Manzano C, Garnery L, Estonba A (2011) Both geometric morphometric and microsatellite data consistently support the differentiation of the *Apis mellifera* evolutionary branch. Apidol 42:150–161
Moritz RFA, Hartel S, Neumann P (2005) Global invasions of the western honeybee (*Apis mellifera*) and the consequences for biodiversity. Eco Sci 12(3):289–301
Narayanan ES, Sharma PL, Phadke KG (1960a) Studies on biometry of the Indian bees III. Tongue length and number of hooks on the hind wings of *Apis cerana indica* F. collected from Madras State. Indian Bee J. 23:3–9
Narayanan ES, Sharma PL, Phadke KG (1960b) Studies on biometry of the Indian bees. 1. Tongue length and number of hooks on the hind wings of *Apis cerana* indica F. Indian Bee J 22:81–88
Neumann P, Koeniger N, Koeniger G, Tingek S, Kryger P, Moritz RFA (2000) Home-site fidelity in migratory bees. Nature 406:474–475
Oldroyd BP, Wongsiri S (2006) Asian honey bees: biology, conservation, and human interactions. Harvard University Press, Cambridge, MA
Oldroyd BP, Osborne KE, Mardan M (2000) Colony relatedness in aggregations of *Apis dorsata* Fabricius (*Hymenoptera, Apidae*). Insects Soc. 47:94–95
Paar J, Oldroyd BP, Kastberger G (2000) Giant honeybees return to their nest sites. Nature 406:475
Pant NC (1985) Bee keeping. In: Handbook in animal husbandry. ICAR, New Delhi, pp 692–711
Pudasaini R, Bahadur TR (2014) Foraging behavior of different honeybee species under natural condition in Chitwan, Nepal. Eur J Acad. Essays 1(9):39–41
Reddy CC (1983) Studies on the nesting behaviour of *Apis dorsata* F. In: Proceedings of the 2nd international conference on apiculture in tropical climates, New Delhi, pp 391–397
Ruttner F (1988) Biogeography and Taxonomy of Honeybees. Springer, Berlin/Heidelberg, p. 284
Ruttner F (1992) Naturgeschichte der Honigbienen. Ehrenwirth, Munich, 357
Ruttner F, Kauhausen D (1985) Honeybees of tropical Africa: ecological diversification and isolation. In: Proceedings of the third international conference on apiculture in tropical climates, Nairobi, Kenya, 5–9 November, 1984, pp 45–51
Ruttner F, Tassencourt L, Louveaux J (1978) Biometrical-statistical analysis of the geographic variability of *Apis mellifera* L. Apidol 9:363–381
Ruttner F, Woyke J, Koeniger N (1972) Reproduction in *Apis cerana*: Mating Behaviour. J Apic Res 11(3):141–146
Seeley TD (1985) Honeybee ecology. Princeton University Press, Princeton, p. 201
Selvakumar P, Sinha SN, Pandita VK, Srivastava RM (2015) Foraging behaviour of honeybee on parental lines of hybrid cauliflower pusa hybrid- 2. Standing Commission of Pollination and Bee Flora. http://apimondiafoundation.org/foundation/files/070.pdf
Sharma HFA (2014) The foraging behaviour of honey bees, *Apis mellifera*: a review. Veterinarni Medicina 59(1):1–10
Sharma AK, Dhaliwal HS, Kakar KL (1974) Insect visitors and pollinators of cauliflower (*Brassica oleracea var. botrytis*) seed crop bloom Himachal. J Agril Res 2:74–78
Sheppard WS (1989) A history of the introduction of Honeybee races into the United States. Am Bee J 129:617–619
Sheppard WS, Meixner MD (2003) *Apis mellifera pomonella*, a new honey bee subspecies from Central Asia. Apidologie 34:367–375

Sheppard WS, Arias MC, Meixner MD, Grech A (1997) *Apis mellifera ruttneri*, a new honey bee subspecies from Malta. Apidologie 28:287–293

Sheppard WS, Meixner MD, Hepparda WSS, Eixnera MDM (2003) *Apis mellifera pomonella*, a new Honeybee subspecies from Central Asia. Apidol 34:376–375

Singh S (1962) Beekeeping in India: 1–214. Indian Council of Agriculture Research, New Delhi

Singh MM (2008) Foraging behaviour of the Himalayan honeybee (*Apis cerana* F.) on flowers of *Fagopyrum esculentum* M. and its impact on grain quality and yield. Ecoprint 15:37–46

Sinha SN, Chakrabarti AK (1980) Bee pollination and its impact on cauliflower seed production. In: Proceedings of the second international conference on apiculture in tropical climates, New Delhi, Feb 29th–Mar 4th, 1980, pp 513–527

Tan NQ (2007) Biology of *Apis dorsata* in Vietnam. Apidol 38:221–229

Thakur ML (1991) Honey and the Honeybees. Indian Council of Forestry Research and Education, Dehradun

Thapa R, Wongsiri S, Oldroyd BP, Prawan S (2000). Migration of *Apis dorsata* in northern Thailand. In: Proceedings of the 4th Asian Apiculture Association conference, Kathmandu, pp 39–43

Tingek A, Mardan MB, Rinderer TE, Koeniger N, Koeniger G (1988) Rediscovery of *Apis vechti* (Maa, 1953): the Saban honeybee. Apidologie 19:97–102

Underwood BA (1990) Seasonal nesting cycle and migration patterns of the Himalayan honeybee *Apis laboriosa*. Natl Geogr Res 6:276–290

Vaudo AD, Ellis JD, Cambray GA, Hills M (2012) Honey bee (*Apis mellifera capensis/A. M. scutellata* hybrid) nesting behavior in the Eastern Cape, South Africa. J South Africa 59(3):323–331

Venkatesh G, Reddy CC (1989) Rates of swarming and absconding in the giant honey bee, *Apis dorsata* F. Proc Indian Acad Sci 98:425–430

Wealth of India (1988) Honeybees, 75–101pp

Woyke J, Wilde J, Wilde M (2000) Swarming, migrating and absconding of *Apis dorsata* colonies. In: Proceeding of the 7th international conference on tropical bees, management and diversity and 5th Asian Apicultural Association Conference, 19–25 March 2000, Chiang Mai, Thailand

Woyke J, Wilde J, Wilde M (2001). Swarming, migration and absconding of *Apis dorsata* colonies. In: Proceedings of the 7th international conference on apiculture in tropical climates, Chiang Mai, pp 183–188

http://www.springer.com/978-981-10-3303-2

Industrial Entomology
Omkar (Ed.)
2017, XI, 465 p. 173 illus., 103 illus. in color., Hardcover
ISBN: 978-981-10-3303-2