Chapter 2
Taxonomy and Distribution of Different Honeybee Species

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Abstract Bee conservation is vital for the functioning of plant communities and human welfare. Unfortunately, bee population is declining in many parts of the world resulting in pollination crisis. The locally adapted strains, subspecies and ecotypes of Honeybees suffer less from elevated losses than non native bees Therefore, their conservation as genetic resource for breeding of disease and stress resistant strains is essential. Besides, a full understanding of origin and distribution of bees is very crucial for understanding how and when these adaptations arose. Understanding the evolutionary relationships of these bees would provide a basis for behavioural studies within an evolutionary framework, illuminating the origins of complex social behaviour, such as the employment of dance and sound to communicate the location of food or shelter. In addition to a global phylogeny, would also provide estimates of divergence times and ancestral biogeographic distributions of the major groups. In this chapter we discuss the origin, taxonomic composition and patterns of distribution of honeybees.

2.1 Introduction

All the species on earth are classified in a taxonomic system that organizes the evolutionary relationships among all the species. Taxonomy is hierarchical, with the highest categories as the most inclusive and the lower categories as the most restricted. The names of the categories are domain, kingdom, phylum, class, order, family, genus, and species. The three domains of life are the Bacteria, the Archaea, and the Eukaryota. All animals, including bees, are members of the Eukaryota domain. The present bee fauna dates back to Cretaceous period which is more that 70 mya (Linksvayer et al. 2012). Bees are members of the kingdom Animalia, the phylum Arthropoda, the class Insecta, and the order Hymenoptera (from the Greek hymen, for membrane, and pteron, for wing). This order includes over 100,000

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diverse species of bees, wasps, ants, and sawflies that have been identified and described. The most important characteristic of most members of this order for the understanding of layman is a “wasp waist” which is narrow area between the thorax and the abdomen. Of course, they also all have two pairs of wings, multi-segmented antennae and a few species have a piercing ovipositor.

Hymenoptera undergo complete metamorphosis, and the males usually develop from unfertilized eggs. Many of the species in this order are social and live in colonies that can be quite large.

Till date, ten species of honeybee belonging to the genus Apis are generally recognized (Engel 1999; Arias and Sheppard 2005). Phylogenetic analyses based on nuclear DNA and mitochondrial (mtDNA) markers strongly support clustering these into three distinct groups: cavity-nesting bees (*A. mellifera*, *A. cerana*, *A. koschevnikovi*, *A. nulensis*), giant bees (*A. dorsata*, *A. laboriosa*, *A. binghami*, *A. nigrocincta*), and dwarf bees (*A. florea*, *A. andreniformis*) (Arias and Sheppard 2005; Raffiudin and Crozier 2007; Tanaka et al. 2001; Willis et al. 1992). Apart from *A. mellifera* all of these species are currently confined to Asia and the lineage that gave rise to extant *A. mellifera* represents an early split from other cavity-nesting bees, so it is most likely that *A. mellifera* can ultimately trace its origin to Asia. Evolutionary relationships among the thousands of bee species that have been classified will undoubtedly continue to change as more information is analyzed, as is happening in the taxonomy of other animals for which the genome has already been mapped. The Western honeybee, *Apis mellifera*, is a species of crucial economic, agricultural, and environmental importance. Due to the activities of beekeepers it is now spread across the entire world, but its native range is large and diverse, spanning Europe, Africa, and the Middle East. After 4 years of work by hundreds of scientists, the sequencing of the 236-million-base genome of the European Honeybee *Apis mellifera* was completed in 2006. This is the fifth insect that has been sequenced to date, and already over 10,000 genes that influence social behavior and physiology have been identified. This new information has been hierarchically organized into a system called Proto Bee to facilitate further study by scientists around the world. The diversity of subspecies is probably the product of a (largely) Early Pleistocene radiation aided by climate and habitat changes during the last ice age. Recently, it is hypothesized that the ancestral stock of cave-nesting Honeybees was separated into the Western group of E Africa and the Eastern group of tropical Asia by desertification in the Middle East and adjacent regions, which caused declines of food plants and trees which provided nest sites, eventually causing gene flow to cease.

2.1.1 The Origins of Honeybees

Fossil evidence is sparse but bees probably appeared on the planet about the same time as flowering plants in the Cretaceous period, 146–74 mya. The evolution of bees is closely tied with a change in food from insect prey to pollen and nectar obtained from flowers of angiosperms. It is thought that bees originally evolved from hunting wasps which acquired a taste for nectar and decided to become vegetarians. The abundance of nectar and pollen changed nutrition mode of some wasps to shift from a predatory existence on larvae (Sphecoidea) to that of collecting nectar and pollen. About 120 mya, the Honeybee developed its morphologies specifically to collect pollen and nectar such as increased fuzziness, pollen baskets, longer tongues, and colonies to store supplies.

The oldest known fossil bee, a stingless bee named *Trigona prisca*, was found in the Upper Cretaceous of New Jersey, U.S.A. and dates from 96 to 74 mya. It is indistinguishable from modern *Trigona*. Although bee resembling *Apis dorsata* but much smaller (about the size of a present day *A. mellifera*) was present in the Upper Miocene (about 12 mya), it has not been possible to estimate when bees of the *A. mellifera*/*A. cerana* type first appeared on Earth. However, it is thought that *Apis florea* and *Apis dorsata* may have existed as separate species as early as the Oligocene period. It is also believed that both *A. mellifera* and *A. cerana* must have acquired separate identities during the latter part of the Tertiary era. The two species were apparently physically separated at the time of the last glaciation and there was no subsequent contact between them until that brought about by human intervention in recent times. In the post glacial period, *A. mellifera* and *A. cerana* (and to a lesser extent *A. dorsata* and *A. florea*) have shown similar evolution into geographical subspecies, or races. Regarding their center of origin, honeybees as a group probably originated in southeast Asia (including the Philippines), as all but one of the extant species are native to that region, including the most primitive living species (*Apis florea* and *A. andreniformis*). The precursor of the Honeybees may have been living about this time, but fossils of the true *Apis* bees appear in the fossil record in deposits dating about 40 mya during the Eocene period; that these fossils are from Europe does not necessarily indicate that Europe is where the genus originated, as the likelihood of fossils being found in southeast Asia is very small, even if that is the true origin.

2.2 Honeybee Speciation and Adaptation

The family Apidae, and specifically the genus Apis are a source of constant aggravation for taxonomists. There are several thousand species and within a single group there can be dramatic differences in the size of the anatomy, making it difficult to determine whether the particular specimen is of one species or another. Globally there are approximately 25,000 named species of bees, with an estimated 40,000 species existing in total. This is why behavioral characteristics count as a significant factor in determining taxonomy. A comprehensive classification must takes into account not only differences in physical characters between subspecies and their present geographical distribution, but also the geological evidence pointing to their origins and to the course of their subsequent evolution and distribution.

- As stated earlier in this chapter, evolving from short-tongued, spheciform wasps, Honeybees first appeared during the Cretaceous period. At that time, present-day continents such as Africa, India, South America, Australia and Antarctica formed a single landmass called Gondwana. The existing dry climate in Gondwanan tropical conditions, led to germination of flowering plants called angiosperms developed colours and petal patterns with abundant nectar to attract bees and other insects. Open-nesting Honeybees perhaps evolved before cavity-nesting bees, probably in India, but evidence is still lacking. In any event, a cavity-nesting Honeybee spread east and north about six mya.
- As Gondwana drifted apart and temperatures cooled dramatically during the Oligocene-Miocene about 35–40 mya, European Honeybees went extinct, while Indo-European Honeybees survived and began to speciate.
- During a Pleistocene warming about 2–3 mya, this bee spread west into Europe and then into Africa to become *A. mellifera*. The fossil record shows that at the time the area of land that is now Europe had a tropical climate. As the climate became cooler the open nesting types would not have been able to survive except by migrating to the tropical region of Southern Asia.
- For the greater part of the Tertiary era, Africa was isolated from Europe by sea and no Tertiary types of Honeybee reached Africa even after a land bridge was established.

The dwarf honeybee, *A. andreniformis* and *A. florea* are only partially sympatric, the palaeoclimatic circumstances under which they may have speciated allopatrically are also considered. A common and widespread pre-*florea*/*andreniformis* split could have occurred in the early Pleistocene followed by the Pre-Pastonian glacial. It is hypothesized that the two species *A. cerana* and *A. mellifera* are still in the beginning states of speciation (Ruttner and Maul 1983). Their distribution into the temperate zone proves a postglacial pattern-therefore they have existed for only about 50,000 years (Ruttner 1988). Arguably the most important change or adaptation in the physiology and behavior in the Apinae family is the development of multi-comb nesting and thermoregulation. These developments allowed the Apis to adapt to diverse climates and led to the major diversification of species and subspecies. A physical separation into two groups probably took place as a result of the glaciations which occurred during the Pleistocene period (1 million to 25,000 years ago) and desert and semi-desert then kept the two groups separate during intervening warm periods. Thus *A. mellifera* and *A. cerana*, although originating from a common stock, evolved into distinct species. While origin of eastern honeybees is well established in Asia, *A. mellifera* is commonly assumed to arise in Asia and expanded into Europe and Africa. However, other hypotheses suggestive of an out-of-Africa expansion for the origin of *A. mellifera* have also been proposed based on phylogenetic trees constructed from genetic markers. The recent analyses do not unequivocally place the root of the tree of *A. mellifera* subspecies within Africa, and are potentially consistent with a variety of hypotheses for honeybee evolution, including an expansion out of Asia (Han et al. 2012). Nevertheless, Hybrid bees called as Africanized Honeybees were brought from Africa to Brazil in the 1950s in hopes of breeding a bee better adapted to the South American tropical climate which reached the Brazilian wild in 1957 and then spread south and north until they officially reached the United States on October 19, 1990.

It is likely that the development of advanced thermal homeostasis in Honeybees which permitted the occupation of cool temperate zones therefore occurred in Southern Asia, possibly in the Himalayan region. This allowed for the *Apis* species to be independent of their environment. It allowed them to live in extremely diverse climates. This in turn gave way to new behaviors including multi comb nesting, and the ability to survive for months of cold weather in a hibernation mode. The success of these adaptations led to the overall increase in Apis territory and species diversification. Once established, the cavity nesting *A. cerana*/*A. mellifera* type would spread East and West, eventually occupying both tropic and cool temperate zones. The distribution and range of *Apis mellifera* is quite large. Various subspecies can be found throughout the world. Their location ranges from Europe, to Asia, to North and South America, and even the Arctic Circle. *Apis mellifera* tend to live in temperate to warm climates, like the Mediterranean and deserts. They typically appear in the Northern climate zones and can live from high mountain ranges to low and dense tropics. It is believed that *Apis mellifera* spread westwards through Asia Minor to colonise the Balkans and the Mediterranean region and southwards through the Arabian Peninsula to occupy Central and Southern Africa. Similarities between neighbouring subspecies also suggest that the Iberian Peninsula and Southern France were colonised from North Africa. No Honeybees could have existed north of the Mediterranean region, the Iberian peninsula and South Western France at the time of the most recent Ice Age. Although at its maximum extent in Western Europe some 18,000 years ago, the ice sheet only reached as far as Northern Britain, the area for hundreds of miles to the south was inhospitable tundra. In the warm period which followed the Ice Age (starting about 14,000 years ago) the ice sheet gradually retreated and the tundra was replaced by forests of birch, pine, hazel, elm and broad-leaved oak. The Western Honeybee was once more able to extend its domain in Europe. In the East advance beyond the Caucasian region proved impossible, owing to the lack of suitable nesting sites in the steppes of Southern Russia. The bees of the Balkan area spread northwards to occupy the Eastern Alpine valleys, Central Europe as far as the 50th parallel of latitude and the Western shores of the Black Sea. In the West, the bees which had found refuge in Southern France during the Ice Age spread across Europe North of the Alps eventually occupying an area from the Atlantic seaboard to the Ural Mountains. The northernmost limit of the territory may have been in Southern Norway; Honeybee remains dating from Ca. 1,200 have been found in an archaeological dig in Oslo although Honeybees had not been reported in Norway prior to the nineteenth century. The mountain ranges of the Alps and the Pyrenees obstructed the northward movement of the bees in the Italian and Iberian peninsulas. However, in colonising this vast territory, stretching from the Urals to the Cape of Good Hope, *A. mellifera* had to adapt itself to a large variety of habitats and climates ranging from the Continental climate of Eastern Europe with its harsh winters, late springs and hot, dry summers, through Alpine, cool temperate, maritime, Mediterranean, semi-desert and tropical environments. This adaptation was achieved by natural selection, producing some two dozen subspecies or races. All the subspecies of the *A. mellifera* group can interbreed given the right conditions, but the crosses show hybridity characters (Fig. 2.1).

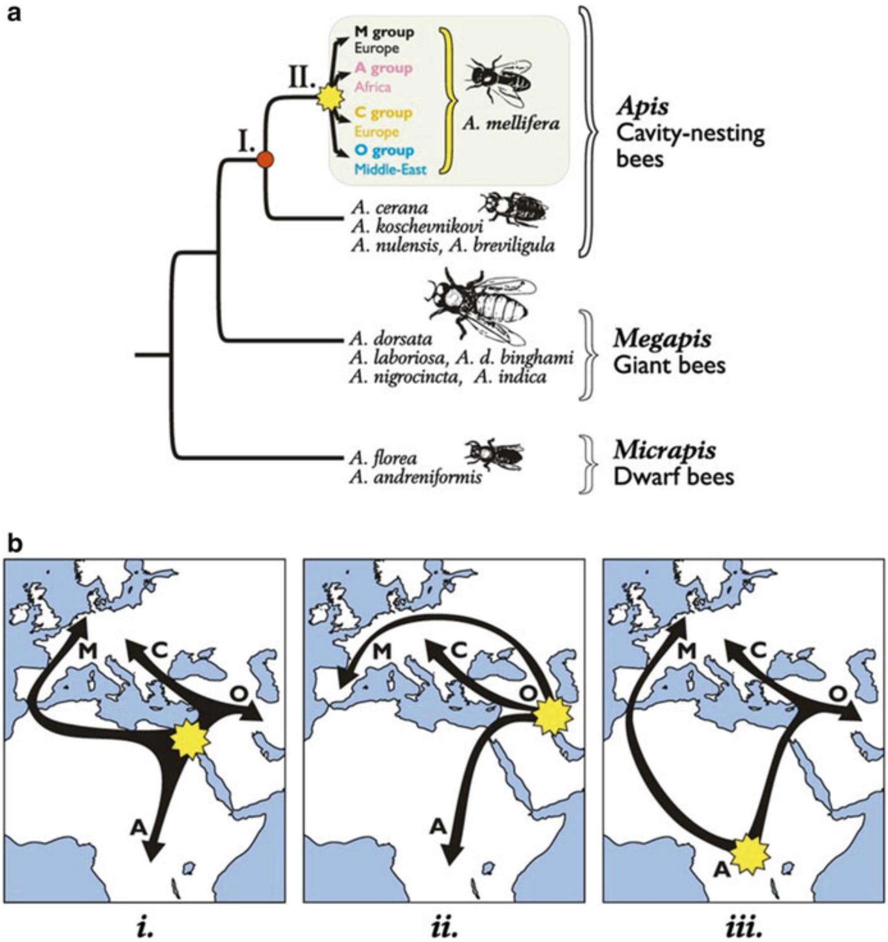

Fig. 2.1 Evolution of *Apis mellifera*

Three hypotheses that have been proposed for the origin of *A. mellifera*.

(i) An expansion from the Middle East, involving colonization of Europe via two routes, one eastern and one western was first suggested by Ruttner (1988) on the basis of morphometric analyses.

(ii) An expansion from the Middle East, which did not involve the western colonization route into Europe was suggested on the basis of trees constructed from mtDNA (Garnery et al. 1992).

(iii) An origin in Africa was proposed by Wilson (1971) and an expansion out of Africa via both an eastern and western route was suggested by the analysis of >1,000 SNPs by Whitfield et al. (2006). The yellow star corresponds to node II in the upper panel.

2.3 Description and Distribution of Honeybees

2.3.1 Honeybee Species

The number of Recent species of *Apis* and their respective diagnoses has been a matter of debate over the last couple of decades. Interpretations varied between as many as 24 (Maa 1953) at the higher extreme to six or seven species on the conservative end (Engel 1999) the most latest being 10 or 11 (Lo et al. 2010). Most of the controversy surrounds the status of some Southeast Asian populations (Koeniger et al. 2010; Radloff et al. 2011). While several analyses have examined *Apis* phylogeny, species recognized in the Engel and Schultz (1997) combined analysis were *Apis mellifera*, *Apis florea* Fabricius, *Apis andreniformis* Smith, *Apis koschevnikovi*, *Apis cerana*, and *Apis dorsata* (these authors did not consider *Apis nigrocincta* specifically distinct from *Apis cerana* at that time). *Apis nigrocincta* was however subsequently added to this list of Honeybee diversity (Hadisoesilo et al. 1995; Hadisoesilo and Otis 1996, 1998; Engel 1999; Smith et al. 2000, 2003) (Fig. 2.2). Out of these nine species the five initial species nest in cavities have a number of combs. The last four are nest in the open and have a single comb. *Apis* species are divided into three lineages: the cavity-nesting bees, *Apis mellifera*, *A. cerana*, *A. koschevnikovi*, *A. nigrocincta* and *A. nuluensis*; and open nesting the dwarf bees, *A. florea* and *A. andreniformis*; the giant bees, *A. dorsata* and *A. laboriosa*. Of the nine species, only *A. mellifera* and *A. cerana* have been "domesticated" for a long time (Koeniger 1976). Most of studies agree that the lineage of dwarf Honeybees,

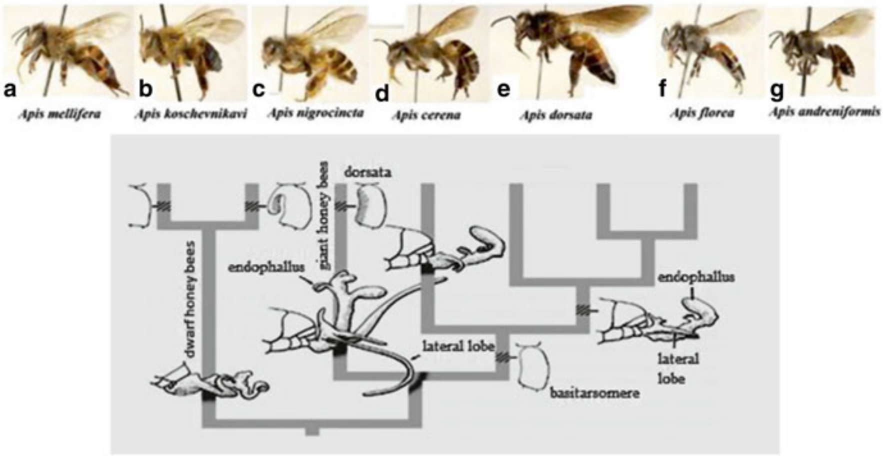

Fig. 2.2 Modern Honeybee diversity (all bees are workers and to the same scale). A. *Apis mellifera* Linnaeus B. *Apis koschevnikovi* Enderlein C. *Apis nigrocincta* Smith D. *Apis cerana* Fabricius E. *Apis dorsata* Fabricius F. *Apis florea* Fabricius G. *Apis andreniformis* Smith their relationship and most important characters for identification

Apis florea and *Apis andreniformis*, diverged early on from the remainder of Recent *Apis* clades, with the giant Honeybees, *Apis dorsata* and its predecessors, diverging from the common ancestor of a clade comprising *Apis mellifera* and the "*cerana*" group of species (i.e., *Apis cerana*, *Apis koschevnikovi*, *Apis nigrocincta*). These three groups are sometimes accorded subgeneric status as *Micrapis* Ashmead, *Megapis* Ashmead, and *Apis* s.str. (Engel 1999, 2001, 2002, 2006; Engel et al. 2009; Koeniger et al. 2011), although some less widely employed classifications have considered them as separate genera in their own right (e.g., Ashmead 1904; Maa 1953; Wu and Kuang 1987). In 1980, the largest bee species in the world, *Apis laboriosa* Smith was reconfirmed from higher altitudes of Nepal and in 1987, the world's smallest bee, *Apis andreniformis* Smith having black body colour and living in Southeast Asia was reconfirmed as an independent species from *Apis florea* Fab. Similarly, in 1988, a red honeybee, *Apis koschevnikovi* Enderlein discovered in Sabah, East Malaysia was another independent species from *Apis cerana* Fab. Then in 1996, *Apis nigrocinta* Smith in Sulawasi Island, Indonesia and *Apis nuluensis* Lin. in same area as the habitat of *Apis koschevnikovi* Enderlein were described as two new species. Hence, among these nine species, eight species are distributed in Asian countries beekeepers and crop farmers need to realize their commercial importance. Then, they could be exploited for pollination different under different agro-climatic conditions. In addition, there are 20,000–40,000 species of honeybees in the world that have to be conserved and utilized their services in pollination (Table 2.1).

2.3.2 Distribution

Honeybee bees have settled almost all over the planet. They live both in regions with cold climates and long severe winters and in the tropics where winters never occur and the summer temperatures are usually higher. Bees' adaptability to different climates and environments has proved to be genuinely amazing. As a result of specific climatic conditions and peculiarities of nectariferous flora, there developed various breeds of honeybees during the course of their evolutionary history. *Apis mellifera* is the most widespread of these species, occurring throughout Europe, Africa, northernwestern Asia (e.g., Ponto-Caspian and as far East as the Tien Shan), the Levant, Caucasia, and the Iranian Plateau (Ruttner 1988, 1992; Ruttner et al. 1985; Sheppard and Meixner 2003), as well as adventive in the Americas and Australia (Kerr 1957; Sheppard 1989; Engel 1999; Moritz et al. 2005). The remaining Recent Honeybees are largely restricted to Asia (Michener 2007; Radloff et al. 2011), with the exception of *Apis florea* which is known also from Jordan, the eastern Arabian Peninsula, and northeastern Africa (Lord and Nagi 1987; Mogga and Ruttner 1988; Engel 1999; Michener 2007; Dathe 2009; Haddad et al. 2009; Moritz et al. 2010). The precise distributions of the remaining Asian species and morphotypes are summarized by Otis (1996), Engel (1999), Oldroyd and Wongsiri (2006), and Hepburn and Radloff (2011) (Fig. 2.3).

Table 2.1 Species specific characters of *Apis mellifera* (Ruttner 1988)

Character	*A. florea*	*A. dorsata*	*A. laboriosa*	*A. cerana*	*A. mellifera*
Forewing length (mm)	6.0–6.9	12.5–13.5	14.2–14.8	7.27–9.02	7.64–9.70
Cubital index	2.8–3.7	6.1–9.8		3.1–5.1	1.65–2.95
Tomenta	Tergite 3–6	3–6	3–6	3–6	3–5
Hind wing: extension of radial vein	Variable	Present	Present	Present	Missing
Drone					
Endophallus	1 pair of cornua bulb a thin tube	4 pairs of very long thin; cornua short bulb	?	1 pair of cornua rudiments 3 others no chitin plates. Thin pad of plumose hair	1 pair of cornua with chitin, plates
Basitarsus 3	Deep incision with plumose hair + spines	Thick pad of sturdy branched hair	?	Thin pad of plumose hair	As *A. cerana*
Behaviour					
Capping of drone cells	Solid	Solid	?	Perforated	Solid
Nest	Single comb encircling twig to form a ‘dance floor’ fixed with cell bases	Single big comb fixed at bottom side of branch or rock, fixed with midrib	As *A. dorsata*	Several combs in cavity fixed with midrib	As *A. cerana*
Communication	Sun-oriented dance on platform open to the sky	Sun-oriented dance on vertical comb open to the sky	?	Sun-oriented dance on vertical comb in cavity	As *A. cerana*
Distribution	Sympatric	Sympatric	?	Sympatric	Allopatric

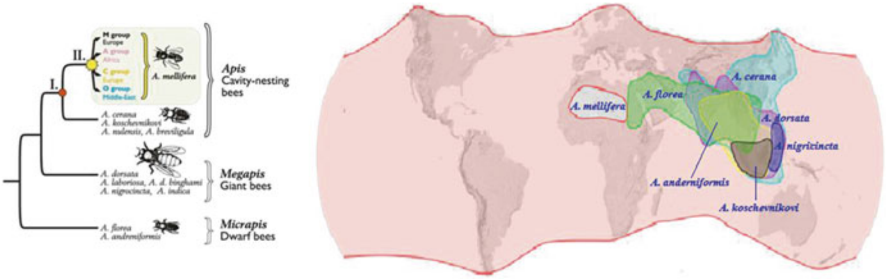

Fig. 2.3 Distribution of Honeybee species

2.3.3 Subgenus Micrapis*: Dwarf Honeybees*

The dwarf honeybees, *Apis andreniformis* and *Apis florea*, are sister species with a partially sympatric distribution in southern Asia. These subtropical and tropical honeybees construct a single comb in the open and are 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 varies regionally, it is almost always associated with the sequence: rainfall > flowering > swarming or migration (Hepburn and Radloff 2011). Swarming and migration are both resource- related, seasonal movements of tropical honeybee colonies that maximize the colonization of new areas and provide a spatial re-fuelling cycle that is clearly driven by r-selection (MacArthur and Wilson 1967; Hepburn and Radloff 2011). The dwarf honeybee, *A. andreniformis*, extends from the eastern foothills of the Himalayas eastward to Indochina, Sundaland and the Philippines. *A. florea* extends from eastern Oman into southern Iran, eastwards along the foothills of the Himalayas and abruptly stops in southern Thailand. A common and widespread pre *florea*/*andreniformis* split could have occurred in the early Pleistocene followed by the Pre-Pastonian glacial (800–1,300 ka) which could well have provided a substantial barrier to gene flow for the then evolving proto-populations of *A. andreniformis* and *A. florea*. They are the most ancient extant lineage of Honeybees, maybe diverging in the Bartonian (some 40 mya or slightly later) from the other lineages, but among themselves do not seem to have diverged a long time before the Neogene (Arias and Sheppard 2005). Unfortunately, accurate identifications of the dwarf honeybees in the older literature are often difficult to assess because the worker bees are morphologically similar However, distinctness of both *A. florea* and *A. andreniformis* as unequivocal, valid biological species is now well established. The most reliable characteristics to rapidly distinguish *A. florea* and *A. andreniformis* were reviewed (Hepburn and Radloff 2011) and presented hereunder:

- In drones, the "thumb" of the bifurcated basitarsus of the hind leg, in *A. florea* is much longer than that of *A. andreniformis*
- The structure of the endophallus is distinct

- The cubital index in worker bees, which, at about three in *A. florea*, is significantly less than that in *A. andreniformis*, which is at about six
- The jugal-vannal ratio of the hindwing, which, at about 75 in *A. florea* is greater than that of *A. andreniformis*, at about 65
- The abdominal tergite 2, which in *A. andreniformis* is deeply punctate, unlike that in *A. florea*
- The marginal setae on the hind tibiae, which in *A. florea* are usually entirely white, while those in *A. andreniformis* are dark-brown to blackish, in sclerotised, non-callow individuals.

2.3.4 Dwarf Honeybee **Apis florea** *Fabricius 1787*

The distribution area of *A. florea* is generally confined to warm climates. In the west, the species is present in the warmer parts of Oman, Iran and Pakistan, through the Indian sub-continent and Sri Lanka. It is found as far East as Indonesia, but its primary distribution centre is Southeast Asia. Rarely found at altitudes above 1,500 m, the bee is absent north of the Himalayas. It is frequently found in tropical forests, in woods and even in farming areas. In Southeast Asia it is almost prevalent in all areas. As its name implies, it is the smallest species of honeybee, both in the body size of its workers and in the size of its nest. In spite of its small size it competes well with other the other *Apis* species (Koeniger 1976). *A. florea* is distributed in the coasts of Persian Gulf, Pakistan, India, Srilanka, Thailand, Malaysia, Indonesia and Philippines (Palawan). The dwarf bee is able to survive in very hot and dry climates with ambient temperatures reaching 50 °C or more. Larger types in north and smaller ones in the south are seen as in other bees.

Phenotypic variation among *A. florea* has not been understood well as the data on these aspects are limiting. Discussing on the variability in *A. florea*, Ruttner (1988) says that there are three geographic types: one found in Sri Lanka and South India; one distributed in Iran, Oman and Pakistan and a third in Thailand. It is possible that all these three types are found in India and the following account of *A. florea* applies equally well to these other types.

Comparisons of geographically separated *A. florea* populations result in morphoclusters that reflect sampling artifacts. These morphoclusters change clinally with latitude but overlap when the full database is contained in the same principal component analysis. In the final analysis, *A. florea* is a single species comprised of three discernible morphoclusters. The northwestern-most bees comprise a morphocluster (1) that is statistically quite distinct from that to the southeast (2); but, they are not isolated, they are joined by large areas of intermediate forms (3) resulting in a continuous cline in morphometric traits within this panmictic species. There are reports of occurrence of another species of dwarf bee, closely resembling *A. florea*, but darker and a little large than it, in tropical semi-evergreen forests in the Western and Eastern Ghats. The abdomen of this type is blackish brown, while *A. florea* has white stripes alternating with orange. It has not been observed in cultivated and inhabited areas. Several univariate morphometric studies on regional or country bases have appeared through the years, but they have not affected the taxonomy of the species.

The comb architecture is similar to that in other *Apis* species, except for the honey storage portion, that is situated at the top, and where the support is free from above, the honey cells are constructed around the support. The number of bees present in a good colony is about 10,000. In small colonies, it is usually half that number. The queen normally lays 350–700 eggs per day (Kshirsagar et al. 1983; Ruttner 1988). Worker bees live longer than those of other *Apis*, usually about 60 days. In areas where *A. florea* usually occurs, the forage is available only in limited periods. Because of this the bee migrates often from one area with bee forage potential to the other. The bees have a short flight range, often hardly reaching 100 m from the nest. The maximum distance it can fly from the nest for foraging is often less than 750 m. In view of this, the honey stored by it is generally unifloral, when floral sources are plenty, The storage capacity of the honey cap in the nest is 500–1,000 g or more (Muttoo 1956; Ruttner 1988). Large colonies in areas rich in bee forage are known to produce upto 4 kg of honey each.

2.3.5 **Apis andreniformis** ***F. Smith (1858)***

The *A. andreniformis* was the second honeybee species to be recognized, and its biology, geographic distribution, and its specific status was recognized by many authors. However, it must be mentioned that the species was only recently separated from *Apis florea* since there are sites where both *A. andreniformis* and *A. florea* live co-specifically. Both species are distributed throughout tropical and subtropical Asia, including Southeast China, India, Burma, Laos, Vietnam, Malaysia, Indonesia (Java and Borneo), and the Philippines (Palawan).

To date, there has been a single univariate morphometric comparison of from South eastern Thailand and Palawan Island in the Philippines (Rinderer et al. 1995). These two widely separated populations (~3,000 km) differed only in a few characters that related to wing and metatarsal lengths, which indicate that it is likely a very homogeneous species. Likewise, estimates of the mt DNA haplotype divergence within the species was about 2 % for *A. florea* and 0.5 % for *A. andreniformis*, indicating rather homogeneous populations in both cases (Smith 1991). Rattanawannee et al. (2007) demonstrated genetic variation based on the sequence analysis of the cytochrome oxidase subunit b, yielded two groups – a result taken as tentative, pending more extensive analyses across the whole area of distribution of *A. andreniformis*.

A. andreniformis nests in quiet forests, generally in darker areas where there is 25–30 % of normal sunlight. Hive can be built between 1 and 15 m from the ground, although the average altitude is 2.5 m. this bee is generally more defensive than *A. florea*, it is known to attack when there are disturbances 3–4 m from the hive. However, it is less aggressive and does not show “trembling” or “shimmering” behaviour as a defensive response. Nests of these bees still pose little danger to the public in general, unless a nest is located in a low bush where one could accidentally knock into. The sting of these bees is not really painful but produces a surprising amount of swelling. Their stings are short and cannot easily penetrate the average adult's skin (except for softer parts such as the underside of the forearm or the neck). They, too, leave their sting in the wound as common honeybees do, and so only sting once. Unfortunately, it is so far not possible (at least from my attempts) to relocate these bees. This is because upon being moved, they will simply swarm to a new location, often back to somewhere near human habitation. During especially hot weather, they frequently land on wet patches on the ground to collect water. Workers constructed resin bands to repel ants, and defended against hornets by shimmering and forming a tail. Workers on the mantle ventilated, head downwards, in the heat of the day when struck by sunlight. Dancing occurred on the crown of the swarm, all but one observed dance of short (1–2 s) duration. One longer, staggering dance may have indicated a pending relocation by the swarm.

2.3.6 Subgenus **Megapis***: Giant Honeybees*

There is one recognized species which usually builds single or a few exposed combs on high tree limbs, on cliffs, and sometimes on buildings. They can be very fierce. Periodically robbed of their honey by human "honey hunters", colonies are easily capable of stinging a human being to death when provoked. Their origin as a distinct lineage is only slightly more recent than that of the dwarf Honeybees. Among them, *Apis dorsata*, the Giant Honeybee proper, is native and widespread across most of South and Southeast Asia while, *Apis dorsata binghami*, is classified as the Indonesian subspecies of the Giant Honeybee or a distinct species; in the latter case, *A. d. breviligula* and/or other lineages would probably also have to be considered species. *Apis dorsata laboriosa*, the Himalayan Honeybee, was initially described as a distinct species. Later, it was included in *A. dorsata* as a subspecies (Engel 1999) based on the biological species concept, though authors applying a genetic species concept have suggested it should be considered a species (Arias and Sheppard 2005). Essentially restricted to the Himalayas, it differs little from the Giant Honeybee in appearance, but has extensive behavioural adaptations which enable it to nest in the open at high altitudes despite low ambient temperatures. It is the largest living Honeybee. *Apis dorsata* and *A. laboriosa* Smith are known as giant or rockbees. The latter species is the largest among the Honeybees in size. It is common in the higher altitudes – between 1,200 and 4100 m. It is not seen in the tropical plains while, *A. dorsata* is common in lower altitudes and in plains, and has a lighter orange brown or tawny body colour. The distribution area of the giant honeybee is similar to that of the dwarf honeybee: it occurs from Pakistan (and, perhaps, parts of southern Afghanistan) in the west, through the Indian subcontinent and Sri Lanka to Indonesia and parts of the Philippines in the east. Its north-south distribution ranges from the southern part of China to Indonesia; it is found neither in New Guinea nor in Australia. While *A. dorsata* is distributed in South China, Celebes and Timor but not Iran or the Arabian Peninsula, it is found in altitudes up to 2,000 m. The giant honeybees of Nepal and the Himalayas have recently been reclassified as *A. laboriosa*. Although minor variations in anatomical, physiological and behavioral characteristics exist among the different geographical races of the giant honeybees, they are essentially similar in all their major biological attributes.

2.3.7 Giant or Rockbee, **Apis dorsata** *F.*

The bee shares the open air, single-comb nesting habits of *Apis florea*, suspending its nest from the under surface of its support, such as a tree limb or cliff. In general, *A. dorsata* tends to nest high in the air, usually from 3 to 25 m above the ground. Nests of *A. dorsata* may occur singly or in groups; it is not uncommon to find 10–20 nests in a single tall tree, known locally as a "bee tree". In India and Thailand, tree harbouring more than 100 nests are occasionally seen in or near the tropical forest. The single-comb nest, which does not have the crest of honey-storage cells typical of *A. florea* nests, may at times be as much as 1 m in width. The organization of the comb is similar to that in the other honeybee species: honey storage at the top, followed by pollen storage, worker brood and drone brood. At the lower part of the nest is the colony's active area, known as the "mouth", where workers take off and land, and where communication dances by scouts, announcing the discovery of food sources, takes place. This dance takes place on the vertical surface of the comb, and during its progress, the bees must have a clear view of the sky to observe the exact location of the sun. Workers of *A. dorsata* are however able to fly at night, when the light of the moon is adequate. It is well known for its viciousness when its nest is disturbed: the mass of defending workers can pursue attackers over long distances, sometimes more than 100 m. Notwithstanding its ferocity, however, this bee's honey is highly prized locally, in some places commanding the best prices in local markets. Two behavioural characteristics of *A. dorsata* are remarkable. First they have a well organized mass defense reaction. An intruder once marked by the odour of a specific pheromone (2-decen-1-yl-acetate) by being stung is followed for kilometers. Second this *A. dorsata* seasonally migrates to locations 100–200 km distant every year. The timing of migration is correlated with the change in the season (rainy to dry period). There is morphometric evidence for different subspecies of *Apis dorsata* .which may eventually be proven to be separate species. *A. dorsata* is the largest of the Honeybees. Two subspecies of *A. dorsata* namely, *A. dorsata breviligula* with short tongue, medium forewing length found in Philippines, beyond Meryll line in east and *A. dorsata binghami* with long tongue and long forewing in Celebes beyond Wallace line in east have been recorded. The large combs (up to 1 m^2) are fixed on the underside of thick horizontal branches of large trees. Sixty or more nests may be found on these bee trees.

2.3.8 The Himalayan Cliff Bee: Apis laboriosa *Smith*

The cliff bee is the world's largest honeybee measuring upto 3 cm long. It has been identified in the mountainous areas of Nepal, Bhutan, India, western Chinese province of Yunnan, (Summers 1990; Batra 1995; Ahmad and Roy 2000) at altitudes of between 1,200 and 3,500 m above sea level (Underwood 1986). It is believed to inhabit other parts of Himalaya. It has been reported to nest mostly between 2,500 and 3,500 m and forages upto 4100 m (Roubik et al. 1985), and that, in general, it builds brood nests under overhangs on vertical cliffs (Underwood 1986; Roubik et al. 1985; Sakagami et al. 1980). Although very little is known about the biology, *laboriosa* certainly exists under extreme ecological conditions. The taxonomic rank is not determined by the morphometric distance but by the isolation and the historical age of the type. *A. laboriosa* nests on cliffs with southerly exposures (Roubik et al. 1985; Underwood 1986). Each Honeybee colony comprises a group of worker and drone bees with one queen, who live together to supply each other's needs and cooperate to raise the off springs .each colony builds one nest consisting of a single large wax comb with a thick honey storage area at the top and thinner brood portion below. Pollen is stored in a band separating the honey storage from the brood comb .the honey portion is usually around 15 cm thick, depending upon the overall size of the comb and the nectar flow potential of the area. Large amounts of *Apis laboriosa* spring honey are exported from Nepal to Japan, Korea and Hong Kong. The red honey is prized in Korea for its medicinal value and fetches a premium price, nowadays Korean companies buy much of this honey in advance. Traditional honey hunting still occurs in South Africa, Southern Arabia, India (the Himalayan regions), and Nepal. The honey hunters in Nepal are mainly from a tribe of Gurungs in central Nepal. The honey hunters in Nepal harvest honey from nests made on cliffs by *Apis laboriosa*, the world's largest honeybee. Harvesters climb down rope ladders, which have been lowered from the top of the cliff, and using bamboo poles maneuver baskets into position beneath the combs. The comb is then cut to fall into the basket. Fires are set at the base of the cliff to pacify the bees to some extent.

Two other morphotypes of giant honeybees have been recognized by some authors as full species: *Apis binghami* Cockerell 1906 of Sulawes, nearby Sula island, and Butang, and *Apis brevligula* Maa 1953 of the Philippines (Luzon, Mindoro, and probably throughout excluding Palawan). The two are quite similar in colour, both being uniformly black with distinct white bands on their abdomen. Both have raised ocelli, as is also the case with *A. dorsata* and are known to forage nocturnally. Some of the differences noted by Maa (1953) are summarized by Ruttner (1988) indicate that *A. breviligula* is slightly shorter but with broader abdomen and substantially shorter mouth parts than *A. binghami* Nesting aggregations which are common for *dorsata* have not been observed for either *brevligula* (Morse and Laigo 1969; Starr et al. 1987) or *binghami*. It could be argued that these two morphotypes should be considered separate species because they have isolated populations with distinct morphological features. However, as their distributions are allopatric from that of *A. dorsata*, their status as species is likely to remain an arbitrary decision.

2.4 Cavity Nesting Bees that Have Parallel Combs: Eastern Species

The oriental honeybee *Apis cerana*, *Apis koschevnikovi*, *Apis nigrocincta*.

2.4.1 Eastern Honeybee, Apis cerana *Fabricius, 1793*

Apis cerana, or the Asiatic honeybee (or the Eastern honeybee), are small honeybees of southern and South eastern Asia, such as China, India, Japan, Malaysia, Nepal, Bangladesh and Papua New Guinea. This species is the sister species of *Apis koschevnikovi*, and both are in the same subgenus as the European honeybee, *Apis mellifera. 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 as Siberia, Northern China and the high mountain area of the Himalayan region (Koeniger 1976).

The several combs of an *A. cerana* colony are built parallel to each other, and a uniform distance known as the “bee space” is respected between them. The body size of the workers of this tree is much smaller than that of the *A. dorsata* workers, and its brood comb consists of cells of two sizes: smaller for the worker brood and larger for the drone brood. The queen cells are built on the lower edge of the comb. As in the other *Apis* species, honey is stored in the upper part of the combs, but also in the outer combs, adjacent to the hive walls. Following the invention of the movable-frame hive for the European honeybee about a century ago, traditional beekeeping with *A. cerana* has been partially replaced by this modern method in several Asian countries, and at the same time attempts have been made – with varying degrees of success – to improve hiving techniques and colony management. Their honey yield is smaller but their beeswax is used to treat and heal wounds. *Apis cerana* is the natural host to the mite *Varroa destructor*, a serious pest of the European honeybee. Having coevolved with this mite, *A. cerana* exhibits more careful grooming than *A. mellifera* and thus has an effective defence mechanism against *Varroa* that keeps the mite from devastating.

2.4.2 Subspecies/Races of Apis cerana

Although *cerana* bees must have shared a common ancestor with *mellifera*, they have evolved into separate species. It is not possible to cross *cerana* with *mellifera* even using instrumental insemination, because the two species are now genetically incompatible and viable eggs do not result from the cross fertilisation. Other differences include their differing reactions to diseases, infestations and predators. *Apis cerana* can tolerate *Varroa* and has developed an effective defence strategy against the Giant Hornet, against which *mellifera* bees have no defence. *A cerana* is however, highly susceptible to the acarine mite, which arrived with the introduction of *mellifera* bees into *cerana* territory. It is also highly susceptible to sac brood and foul brood, but not markedly so to *Nosema*. A high degree of variation in size and coloration probably reflect the ecological diversity of *A. cerana*. The influence of latitude and altitude on the size of worker bees was also found for *A. cerana* in Vietnam. This wide range has led to important variations among the bee's geographical races: particularly between the tropical and temperate races, there are wide differences in workers' body size, nest size, colony population and swarming and absconding behaviour, The temperate and sub-tropical races appear to store greater quantities of food than the tropical races, which in turn are more mobile than the former, tending to swarm, abscond and migrate quite frequently. 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 International Centre for Integrated Mountain Development (ICIMOD) reveal that *Apis cerana* populations can be divided into three sub-species, namely *Apis cerana cerana*, *Apis cerana himalaya* and *Apis cerana indica*. Of these, *Apis cerana cerana* is distributed over North-west Himalayas in India, North-West Frontier Province of Pakistan and Jumla region of Nepal. *Apis cerana himalaya* is found in hills of Nepal, Uttar Pradesh, North-East Himalayas and Bhutan, *Apis cerana indica* is found in plain areas and foothills of the region. Similar studies carried out in China reveal presence of five sub-species of *Apis cerana*. These include *Apis cerana cerana*, *Apis cerana skorikovi*, *Apis cerana abaensis*, *Apis cerana hainanensis* and *Apis cerana indica* (Zhen Ming et al. 1992; Partap 1999). Among 13 putative subspecies names (trinomials names) of *Apis cerana* in China since 1944, the trinomials (subspecies) of Apis cerana F., which published since 1970, were not valid under modern ICZN rules, 4th edition, 1999 and according to nomenclatural standing in Apis classification. The morphometric analysis of *Apis cerana* F. in China showed that the "Chinese Eastern race" belonging to "*Apis cerana cerana*" and the "South Yunnan race" being "*Apis cerana indica*", the "South Yunnan race" and the "Aba race" (*Aba cerana*) could be discriminated. However, this analysis failed to discriminate among "South Yunnan race" (*Apis cerana indica*), "Hainan race" (Hainan *cerana*) and "Tibet race" (Tibet cerana). Molecular analyses revealed that the mitochondrial genotypes of *A. cerana* were the same as that of all sample originated from India, Japan and Korea without variation and belonging to "Mainland Asia" group of *Apis cerana*. It was approved that there were abundance for mitochondrial genotypes of *A. cerana* in Southern Gansu and Northern Aba area. It could be said certainly that in China the members of "Aba race" (*Aba cerana*) was existence. The description about following species is available in literature.

1. ***Apis cerana cerana*** – This subspecies with the biggest body size of *A. cerana* occurs in northern parts of China, in the northwest of India, in the north of Pakistan and Afghanistan, and in the north of Vietnam. On average, the proboscis and forewing length measure 5.25 and 8.63 mm respectively and found in Afghanistan, Pakistan, north India, China and north Vietnam
2. ***Apis cerana indica*** – This is the subspecies with the smallest body size. It lives in the south of India, in the south of Thailand, Cambodia and Vietnam, in Malaysia, in Indonesia and in The Philippines. The length of proboscis and forewing is 4.58–4.78 mm and 7.42–7.78 mm respectively (Ruttner 1988). It is distributed in South India, Sri Lanka, Bangladesh, Burma, Malaysia, Indonesia and the Philippines

3. ***Apis cerana japonica*** – This subspecies is endemic in Japanese temperate climates except the island of Hokkaido. This subspecies is divided into two separate ecotypes: Honshi and Tsushima. The body size of *Apis cerana japonica* is relatively big, with an average proboscis length of 5.18 mm and an average forewing length of 8.69 mm. *A. c. japonica* gradually has been replaced by introduced *A. mellifera* (Okada 1986).
4. ***Apis cerana skorikovi*** ("himalaya") or ***Apis cerana himalayana*** – The body size of this subspecies is intermediate between *A. c. cerana* and *A. c. indica*. It occurs in the east of the Himalayas from Nepal to northern Thailand. On average, the proboscis and forewing length measure 5.14 and 8.03 mm respectively. It is native to Asia between Afghanistan and Japan, and from Russia and China in the north to southern Indonesia. Recently introduced to Papua New Guinea and found in Central and east Himalayan mountains (Ruttner 1988) *running. Apis cerana* builds a nest consisting of a series of parallel combs, similar to *Apis mellifera*, and builds its nest within a cavity.
5. ***Apis cerana nuluensis*** – is a subspecies of honeybee described in 1996 by Tingek, Koeniger and Koeniger. The geographic distribution of the subspecies is the south-east Asian island of Borneo, politically divided between Indonesia, Malaysia, and Brunei. *A. c. nuluensis* is one of a number of Asiatic honeybees, including the more obscure *Apis koschevnikovi* and *Apis nigrocincta* (the latter of which has nearby habitat on nearby Sulawesi and Mindanao islands). While this was originally described as a species, it has since been determined to represent a geographic race (subspecies) of the widespread *A. cerana* (Engel 1999). Like many honeybees, *A. c. nuluensis* is liable to infestation by the parasitic *Varroa* mite, although in this case the particular species is *Varroa underwoodi*. (In this aspect, *A. c. nuluensis* is similar to *A. nigrocincta*)

Very recently Radloff et al. (2010) have classified this bee into six clusters cited hereunder:

1. Morphocluster I: named "Northern *cerana*". The bee extends from northern Afghanistan and Pakistan through northwest India, across southern Tibet, northern Myanmar, China and then northeasterly into Korea, far eastern Russia and Japan. Morphocluster I bees have been previously named as follows: *A. skorikovi*, *A. c. abansis*, *A. c. abanensis*, *A. c. bijjieca*, *A. c. cathayca*, *A. c. cerana*, *A. c. fantsun*, *A. c. hainana*, *A. c. hainanensis*, *A. c. heimifeng*, *A. c. indica*, *A. c. japonica*, *A. c. javana*, *A. c. kweiyanga*, *A. c. maerkang*, *A. c. pekinga*, *A. c. peroni*, *A. c. skorikovi*, *A. c. shankianga* and *A. c. twolareca*. Six subclusters or populations are morphometrically discernible within this morphocluster:
    (a) an "Indus" group in Afghanistan, Pakistan and Kashmir
    (b) a "Himachali" group in Himachal Pradesh, India
    (c) an "Aba" group in southern Ganshu and central and northern Sichuan provinces in China, northern China and Russia (larger bees)
    (d) a subcluster in central and eastern China
    (e) a "southern" cerana subcluster in southern Yunnan, Guangdong, Guangxi and Hainan in China and
    (f) a "Japonica" group in Japan and Korea .

2. Morphocluster II, here named "Himalayan *cerana*". This includes the bees of northern India: (a) northwest, (c) northeast; and some of southern (c) Tibet and Nepal. Morphocluster II bees have previously been named *A. c. skorikovi*, *A. c. indica*, *A. c. himalayana*, and *A. c. himalaya*.

   Two subclusters are discernible within this morphocluster:

   (a) the bees of the northwest the "Hills" group, and
   (b) those of the northeast, the "Ganges" group .

3. Morphocluster III, here named "Indian Plains *cerana*" occurs across the plains of central and southern India and Sri Lanka as a fairly uniform population, long known as "plains *cerana*" for this subcontinent . Morphocluster III bees have only previously been termed *A. c. indica*.
4. Morphocluster IV, here named "Indo-Chinese *cerana*" form a compact group in Myanmar, northern Thailand, Laos, Cambodia and more southern Vietnam. Morphocluster IV bees have been previously named *A. c. indica* and *A. c. javana*.
5. Morphocluster V, here named "Philippine *cerana*" is restricted to the Philippines, but excluding most of Palawan Island The bees of this cluster have been previously named *A. philippina*, *A. c. philippina* and *A. c. samarensis*. Within these islands there are subclusters and we term these bees respectively after the major island groups there: "Luzon" bees, "Mindanao" bees, and "Visayas" bees.
6. Morphocluster VI, here named "Indo-Malayan cerana", extend from southern Thailand, through Malaysia and Indonesia. This large area consists of a morphometrically rather uniform bee below the South China Sea. Morphocluster VI bees have been previously termed *A. cerana*, *A. indica*, *A. javana*, *A. c. johni*, *A. lieftincki*, *A. peroni*, *A. vechti linda* and *A. v. vechti*.

   Three subclusters are discernible within this morphocluster:

   (a) Philippines (Palawan), Malaysia (North Borneo), Indonesia (Kalimantan) bees
   (b) Malay Peninsula, Sumatera, and some Sulawesi bees
   (c) Indonesia (Java, Bali, Irian Jaya, some Sulawesi and Sumatera) bees

2.5 Ecotypes

Comprehensive studies on the biometry and taxonomy of *A. cerana* in India revealed intra-specific variation in Indian *A. cerana* into seven ecotypes indicated by Kshirsagar (1983), and redefined here (Table 2.2). It is possible that by further detailed investigations, additional ecotypes and races can be found.

2.5.1 Apis nigrocincta *Frederick Smith, 1861*

Apis nigrocincta is a species of honeybee that inhabits the Philippine islands of Mindanao and Sangihe as well as the Indonesian island of Celebes or Sulawesi. The species builds nests in cavities like the closely related *Apis cerana*. In fact, there are

Table 2.2 Ecotypes of *Apis cerana* F. in India

Geographic region	Latitude	Altitude	Location of sample collection	Remarks
Kashmir Valley	34°05′	1,586	Srinagar, Jammu and Kashmir	Largest ecotype in the country
Western Himalayas	31°43′	761	Mandi, Himachal Pradesh	Possibly includes the next two variants
Western Sub-Himalayas	30°05′	700	Kangra, Himachal Pradesh	Possibly variant of Western Himalayas
Western Sub-Himalayan Foot Hills	30°10′	630	Ranipokhari, Uttar Pradesh	Possibly variant of Western Himalayas, and not ecotype
Eastern Himalayas	26°53′	1,500	Kurseong, West Bengal	Verma (1992) proposes 3 races in this region
Indo-Gangetic Plains and Aravali Hills	29°13′	440	Haldwani, Uttar Pradesh	Mahabaleshwar included due to its high altitude
	26°06′	53	Muzaffarpur, Bihar	
	26°05′	54	Guahati, Assam	
	24°36′	1,195	Mount Abu, Rajasthan	
	17°56′	1,382	Mahabaleshwar, Maharashtra	
Central	20°48′	27	Cuttack, Orissa	
Peninsula	17°50′	767	Lammasingi, Andhra Pradesh	
	17°00′	670	Petlond, Maharashtra	
Western and Eastern Ghats	15°20′	700	Castle Rock, Karnataka	Kodaikanal included due to its high altitude
	14°57′	700	Yellapur, Karnataka	
	12°57′	650	Sakleshpur, Karnataka	
	10°14′	2,343	Kodaikanal, Tamilnadu	
Western and Eastern Peninsular Coastal strips	14°25′	0	Kumtha, Karnataka	Smallest ecotype in the country
	11°55′	0	Pondicherry, Pondicherry	
	10°46′	97	Palghat, Kerala	
	08°44′	51	Tirunelveli, Tamil Nadu	
	08°05′	37	Kanyakumari, Tamil Nadu	

Source: Kshirsagar (1983)

few substantial differences between the two species: the genitals of the respective drones, for instance, are identical. However, there are small morphological differences, genetic polymorphism in the mitochondrial DNA, as well as behavioral differences. In areas where the *A. cerana* and *A. nigrocincta* live together, they can most immediately be distinguished by their coloration and size: *A. cerana* tends to be darker and smaller, while *A. nigrocincta* tends to be larger and have a yellowish clypeus (the lower area of the face). The architecture of the colonies is also a point of difference: the opening of the drone cell of *A. cerana* is covered in wax, under which there is a conical cocoon with a central hole or pore. In *A. nigrocincta*, however, the cell of the drone has a narrow opening, without a hard wax cap and hole. In addition, the queens of *A. nigrocincta* generally create colonies with greater numbers of drones than those of *A. cerana*. Another noticeable behavioral difference between the species is the time of day at which they prefer to gather pollen. *A. nigrocincta* contracts the parasite-caused honeybee disease varroatosis by playing host to the species of *Varroa* mite known as *Varroa underwoodi*. In this way, they are similar to *Apis cerana nuluensis*, which is also susceptible to the same species of parasite.

2.5.2 Apis koschevnikovi *Buttel-Reepen, 1906*

Koschevnikov's Bee, or *Apis koschevnikovi*, is a species of honeybee which inhabits Sabah, Malaysian and Indonesian Borneo, where it lives conspecifically with other honeybee species such as *Apis cerana* (specifically *A. c. nuluensis*). The individual bees are slightly larger than *Apis cerana* found in the same locality, but otherwise the colonies are similar in size and construction. Other names: the red bee (this species was named for a short period *Apis vechti*). The species was first described by Buttel-Reepen, who dedicated it to Koschevnikov, a nineteenth century pioneer of honeybee Morphology. 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. *A. koschevnikovi* hosts a unique species of the honeybee parasite *Varroa*, named *Varroa rindereri*. (Guzman et al. 1996; De Guzman and Delfinado-Baker 1996) Although this parasite species is quite similar to *Varroa jacobsoni* it is perfectly differentiable. It has only been reported in colonies of *A. koschevnikovi* in Borneo and seems to be specific to that species, as it has yet to be observed crossing over to colonies of *A. cerana*, even when they live in the same apiary.

2.5.3 The European, Honeybee, Apis mellifera *Linnaeus 1758*

Western (European, Common) Honeybee "Mellifera" is from the Latin, and means honey-carrying – hence "*Apis mellifera*" is the honey-carrying bee. The name was coined in 1758 by Carolus Linnaeus, though in a subsequent 1761 publication, he referred to it as *mellifica*; the older name has precedence, but some Europeans still utilize the incorrect subsequent spelling. This species of Honeybee is native to Africa, most of Europe and the Middle East. It has been introduced by man to the Americas, Australasia and much of the rest of the world. There are many subspecies that have adapted to the local geographic and climatic environment. Generally *Apis mellifera* are regarded as the medium-sized Honeybees, against which other species are judged as "large" or "small". In the wild, the natural nesting sites of *A. mellifera* are similar to those of *A. cerana*: caves, rock cavities and hollow trees. The nests are composed of multiple combs, parallel to each other, with a relatively uniform bee space. The nest usually has a single entrance. The temperate races prefer nest cavities of about 45 l in volume and avoid those smaller than 10, or larger than 100 l. Colonies of the European races are composed of relatively large populations, usually between 15,000 and 60,000. Anthropomorphically speaking, this behaviour of the temperate races is obviously an evolutionary advantage: without it, the colony faces starvation during the cold winter months, when food is not naturally available and the temperature is too low to permit flight activity.

2.6 Subspecies or Races

The Western honeybee or European honeybee (*Apis mellifera*) is a species of honeybee comprised of several subspecies or races (Table 2.3; Fig. 2.4). 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 behavioral 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 *Apis mellifera*, some tropical, others temperate. The Africanized Honeybees in South and Central America are descended from tropical African *Apis mellifera* Different races of *Apis mellifera* have different sizes of individual bees and colonies. The shortage of natural forage and the cold temperatures prevailing from late autumn until early spring appear to play an important role in exercising rigid natural-selection pressures on the colonies. As a result, both feral and hived colonies of temperate-zone *A. mellifera* are less likely to abscond than the tropical races. This bee has been differentiated into geographic subspecies as they spread from Asia into Europe and Africa. There are currently 28 recognized subspecies of *Apis mellifera* based largely on these geographic variations. The races include *Apis mellifera adansonii*, *A. m. scutellata*, *A. m. littorea*, *A. m. monticola*, *A. m. unicolor*, *A. m. lamarkii*, *A. m. major*, *A. m. yementica*, *A. m. major*, *A. m. capensis* and *A. m. intermissa* (Table 2.3). These subspecies have been found to have specific behavioral and morphological characteristics. All subspecies are cross fertile. Geographic isolation led to numerous local adaptations as this species spread after the last ice age. These adaptations include brood cycles synchronized with the bloom period of local flora, forming a winter cluster in colder climates, migratory swarming in Africa, enhanced foraging behavior in desert areas, and numerous other inherited traits. The 28 subspecies can be assigned to one of four major branches based on work by Ruttner and subsequently confirmed by analysis of *mitochondrial* DNA (Cornuet and Garnery 1991). African subspecies are assigned to branch A, northwest European subspecies to branch M, southwest European subspecies to branch C, and Mideast subspecies to branch O. The subspecies are grouped and listed. The Western Honeybee is the third insect, to have its genome mapped. The genome is unusual in having very few

Table 2.3 Races of *Apis mellifera* (Modified from Drescher and Crane 1982; Winston 1987)

Race	Distribution	Strength	Weakness	Physical character/tongue length/cubital index
Apis mellifera ligustica, classified by Spinola, 1806 – the Italian bee	North and south America, Europe. They are kept commercially all over the world	Very gentle, low swarm, and produce a large surplus of honey. coloured	So they require more winter stores (or feeding) than other temperate zone races	Abdomen with bright yellow bands/6.3–6.6/61.4
Apis mellifera carnica, classified by Pollmann, 1879 – Slovenia – better known as the Carniolan honeybee	It is a mountain bee in its native range, and is a good bee for cold climates	Extremely gentle require low feeding in winter, and build very quickly in spring	It does not do well in areas with long, hot summers	Grey or brown in colour/6.4–6.8/51.2
Apis mellifera caucasica, classified by Pollmann, 1889 – Caucasus Mountains	Caucasus USSR	This sub-species is regarded as being very gentle and fairly industrious	Some strains are excessive propolizers very susceptible to *Nosema* low honey yielder, poor pover winterer	Similar to carnica Upto 7.2/54.7
Apis mellifera remipes, classified by Carl Eduard Adolph Gerstcker 1862 –	Caucasus, Iran, Caspian lake. Armenia, east Anatolia, Iran			
Apis mellifera mellifera, classified by Linnaeus, 1758 – the dark bee of northern Europe also called the German Honeybee –	Domesticated in modern times, and taken to North America in colonial times	Medium honey yields, over winters well	Aggressive however, applies to the hybrid *A. m. mellifera* x *A. m. ligustica* populations found in North America and Western Europe, not to the near-extinct "pure" *A. m. mellifera*. poor spring and early summer performance	Body large, brood dark with yellow spots 5.7–6.4

(continued)

Table 2.3 (continued)

Race	Distribution	Strength	Weakness	Physical character/tongue length/cubital index
Apis mellifera iberiensis, classified by Engel, 1999 – the bee from the Iberian peninsula (Spain and Portugal)			They do a great use of propolis. The movements are fast and rather nervous. Quick defensive reaction, nervousness, propensity to swarm	It is mostly dark brown to jet-black. The queens are black almost uniform in color
Apis mellifera cecropia, classified by Kiesenwetter, 1860 – Southern Greece				
Apis mellifera cypria, classified by Pollmann, 1879 – The island of Cyprus –			This sub-species has the reputation of being very fierce compared to the neighboring Italian sub-species, from which it is isolated by the Mediterranean Sea	
Apis mellifera sicula, classified by Montagno, 1911 – from the Trapani province and the island of Ustica of western Sicily				
Apis mellifera acervorum Russia				

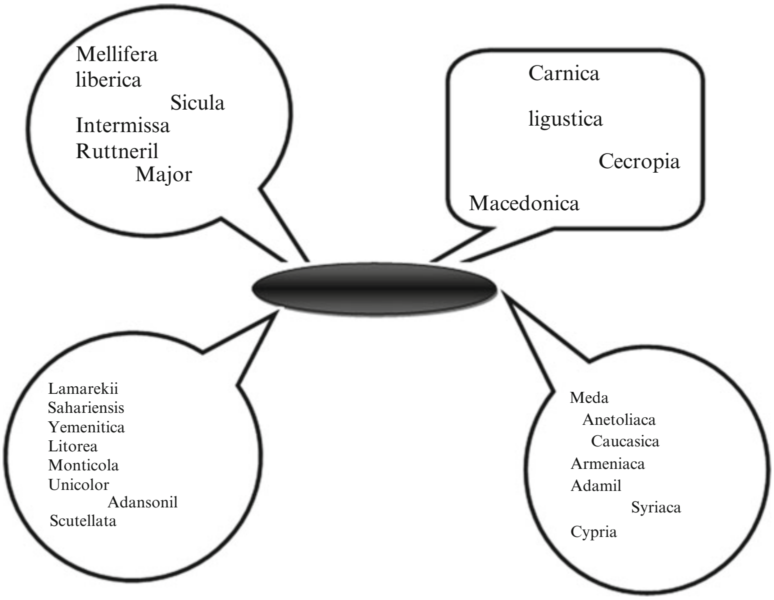

Fig. 2.4 Evolution of honeybee species

transposons. According to the scientists who analysed its genetic code, the western Honeybee originated in Africa and spread to Europe in two ancient migrations. They have also discovered that the number of genes in the Honeybees related to smell outnumber those for taste. The genome sequence revealed several groups of genes, particularly the genes related to circadian rhythms, were closer to vertebrates than other insects. Genes related to enzymes that control other genes were also vertebrate-like.

2.6.1 Subspecies Originating in Europe

European honey bees represent a complex of several interbreeding European subspecies that have been spread extensively beyond its natural range. Presently, European honey bees are naturalized on all continents except Antarctica.

2.6.2 Subspecies Originating in Africa

The tropical African races form their own group distinguishable by multivariable analysis (Ruttner and Kauhausen 1985) (Table 2.4). The distribution of these races is depicted in (Fig. 2.5) while the measured values of important characters are presented in Table 2.5. The two dominant African races of *A. mellifera* are *A. m. scutellata* in East Africa from Ethiopia to Southern Africa and *A. m. adansonii* which

Table 2.4 African races of *Apis mellifera*

Race	Geographical distribution	Physical characteristics	Tongue length (mm)	Temperament Aggressiveness Swarming Absconding Remarks
African races				
Apis mellifera intermissa Buttel-Reepen (Telian bees)	North Africa from Libya to Morocco	Body long, dark pigment sparse hairs	6.4	Strong Strong Strong Strong reproductive swarming
Apis mellifera major Ruttner	Small pocket in RIF mountain Morocco	Body long, broad and dark with yellow markings	7.0	Medium – – Biology little known
Apis mellifera lamrckii Cockerell (Egyptian bees)	Northeast Africa, Egypt and Sudan along the Nile valley	Medium sized to long slender, body intense yellow colour, broad toments	5.7	Medium – – Many swarm cells
Apis mellifera nubica Ruttner	Sudan	Small bees with slender body intense yellow colour	5.4	Strong – – Little known about biology
A.m. sahariensis	In north oasis near northern edge of Sahara	Bees are medium sized, slender body having yellow markings	6.3	Strong – – Well adapted to environmental conditions
A.m. jementica Ruttner	Yemen	Small bees with broad having intense yellow colour of hairs	5.4	– – – Little known about biology
A.m. littorea Smith	Coastal areas of Tanzania	Small bees with relatively slender body having yellow tergites	5.7	Strong Strong – Intense brood production
A.m. scutellata Lepeletier (East African bees)	Ethiopia, Kenya, Tanzania, Burundi, Zimbabwe, South Africa	Bees are small slender body with intense yellow colour	5.9	Strong Strong Strong Intensive reproductive swarming

(continued)

Table 2.4 (continued)

Race	Geographical distribution	Physical characteristics	Tongue length (mm)	Temperament Aggressiveness Swarming Absconding Remarks
A.m. monticola Smith (mountain bees) Lepeletier (East African bees)	Mount regions of Tanzania, Kenya, Ethiopia	Bees with long body, having dark colour, long hairs	6.2	Low Strong – Gentle in comparison to other African races
A.m. capensis	Southern tip of africa	Small slender body, relatively dark in colour	5.9	Medium – – Fast ovariole development and ability to lay parthoeno genetic females
A.m. unicolor	Madagascar	Small slender, body relatively dark in colour	5.6	Low – – Fly off combs readily
A.m. adansonii Latreille west African bees)	West Africa south of Sahara	Medium sized bees, broad body having yellow markings	6.2	– Strong – Migratory swarming
Apis mellifera major, classified by Ruttner, 1978 -	from the Rif mountains of Northwest Morocco			This bee may be a brown variety of the *Apis mellifera intermissa* but there are also anatomic differences

predominates in West Africa. Both species are smaller compared to the European Honeybee and their colonies produce more swarms. For instance, *A. m. lamarckii* found in lower Nile valley is a small relatively defensive race and has black with yellow abdominal bands while *A. m. intermissa* is found from Libyan Desert to the Atlantic coast. This race is black, produces much propolis and stings readily. The most studied and commonly used race in beekeeping development programmes is *A.m. scutellata*. This race spreads from Ethiopia to South Africa. In tropical Africa, significant geographical variability in honeybee races is quite evident in spite of lack of physical barriers. According to Fletcher (1978), the mechanism that brings about isolation is the selective adaptation of races of bees to certain biotopes. The existing information indicates that throughout Africa honeybee races are quite unpredictable in their defensive behavior and this has caused a lot of fear in beekeeping due to the number of deaths reported on people and domestic animals. For

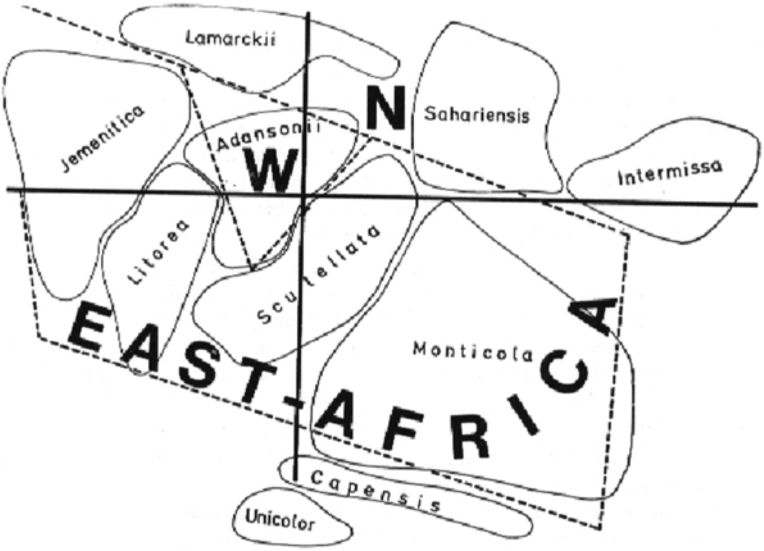

Fig. 2.5 Distribution of African races according to direction in Africa

Table 2.5 Measured values of seven characters of *A. m. scutellata* compared with the values obtained from other four races (given as difference to *scutellata* and to *A. m. intermissa*)

Character	*yemenitica*	*litorea*	*adansoni*	*scutellata*	*monticola*	*intermissa*
Proboscis (mm)	–0.47	–0.07	–0.17	5.86	+0.20	+0.52
Hind leg (mm)	–0.48	–0.30	–0.10	7.58	+0.10	+0.54
Length of forewing (mm)	–0.56	–0.26	–0.21	8.66	+0.19	+0.52
Length of tergite 3+4 (mm)	–0.28	–0.25	–0.16	4.17	±0.0	+0.26
Colour of tergite 4 (Scale from 0.0=completely dark to 9.0=completely yellow)	+1.06	+0.21	+0.35	4.00	−1.01	–2.90
Cubital index	–0.26	–0.27	–0.13	2.52	–0.18	–0.30
Angel of wing venation 16	+ 0.21	–1.09	+ 2.55	92.40	–6.00	+ 3.36

example, in Uganda, honeybees at higher altitudes in the western part of the country have been found to be more aggressive than those found in other areas of the country (Corner 1984). Further, a clear correlation has been found between climate and morphometric characters in tropical Africa. This has been shown by bee races in East Africa with striking differences in size across a distance of 250 km between the coast of Indian Ocean and the tropical rain forest of Kilimanjaro. In this region, the smallest race occurs in the hottest areas, and the largest at higher altitude with low temperatures (Ruttner and Kauhausen 1985). Current studies have revealed lack of homogeneity in races that were initially thought to belong to certain localities. For instance, intermissa a northwestern race in Africa has two morphoclusters that have been revealed by multivariate methods that a subspecies or race is based on the recognition of distinct population and should be different from the neighboring populations is still debatable. The current literature shows evidently that each of the African honeybee sub-species differs morphologically and behaviorally (Hepburn and Radloff 1997) and their variation has some implications for beekeeping practice. Several researchers and beekeepers describe a general trait of the African subspecies which is absconding, where the Africanized honeybee colonies abscond the hive in times when food-stores are low, unlike the European colonies which tend to die in the hive. The variation in African tropical bees therefore show a clear diversification and isolation by ecological factors and the correlation between adaptive characteristics and environmental factors is much more evident in tropical Africa than in other parts of the world. The observed spatial variability between the subspecies enhances preservation of gene pools for beekeeping industry in East Africa. Further, the hybrids or intermediates produced occupy transitional zones reflecting intermediate ecological zones. Some races are distinguishable and locally classified as:

Saki – This race is most common Honeybee in Kitui. Small but with ferocious nature. Yellow stripe present in the abdomen. Body size is small but it makes a bigger hive compared with that of group 2 nzingu.

Nzingu – It is rather larger in size with milder nature compared to saki tinted as a whole black

Ikalamata – This one is further larger than the group 2 nzingu. Bearing reddish brown and yellowish hair. Particularly legs are covered with thick hairs. Wings do not rest while reposing.

Wuli – Characterized by reddish body it is larger than group 1 saki. Its queen bee is very big, laying eggs, only one is found in the center of a beehive.

2.6.3 Subspecies Originating in the Middle East and Asia

Middle East and Asia is a zone of high morphological diversification and evolution for honeybees. Many clearly distinct races have evolved within this region, which includes a diversity of habitats. Asia Minor, including Anatolia, appears to be the genetic center for these honeybee subspecies. Honeybee races in this region include the subspecies *Apis mellifera anatoliaca*, *A. m. caucasica*, *A. m. meda*, and *A.m. syriaca*, which were considered by Ruttner to form a basal branch of the species. *Apis mellifera anatolica*, classified by Maa (1953) is typified by colonies in the central region of Anatolia in Turkey and Iraq (Range extends as far West as Armenia). It has many good characteristics but is rather unpleasant to deal with in and around the hive. *Apis mellifera syriaca*, classified by Skorikov 1829 – (Syrian honeybee) Near East and Palestine. Another subspecies that are found are *Apis mellifera macedonia*, classified by Ruttner 1988 – Northern Greece, *Apis mellifera ruttneri*, classified by Sheppard, Arias, Grech and Meixner 1997, *Apis mellifera adamii*, classified by Ruttner 1977 – Crete, *Apis mellifera armeniaca*, Mid-East, Caucasus, Armenia, *Apis mellifera yementica* – Yemen and Oman. *Apis mellifera pomonella*, classified by Sheppard and Meixner 2003 – Endemic Honeybees of the Tien Shan Mountains in Central Asia. This sub-species of *Apis mellifera* has a range that is the farthest East Sources. Most of these species appears similar to *linguistic*. However, information about their biology is scanty. Nevertheless they are being managed for honey in many countries.

2.7 Hybridization

Some species have evolved as a result of hybridization. For example, in the Iberian Peninsula which is an area of hybridization between the north of Africa and Europe, *Apis mellifera mellifera*, is localized in the northern, *Apis mellifera intermissa*, and *A. m. iberiensis* are naturally present too. *A. m. iberica* haplotype is present in the Honeybees of the western United States where the Honeybees are not native and they were introduced from Spain during the conquest of America. Presents six haplotypes different, five of them correspond to an evolutionary lineage from Africa and one from West Europa. From this, infer the hybrid nature of this subspecies, which has a predominant influence in the south of the Iberian Peninsula, with a North African component that is gradually replaced towards the north, through the lineage of *Apis mellifera mellifera*. The genetic variability of the microsatellite of the chromosomes, is similar to that of African populations in the number of alleles detected and the values of genetic diversity.

The different races of *A. mellifera* can generally be differentiated in physiological terms. Bees from warmer climates tend to be smaller in size and lighter in colour than those adapted to the colder regions, although this rule is not invariable. The effect of altitude seems to be similar to that of increasing latitude. Accurate differentiation between races of similar appearance requires precise morphometric examination of representative samples of bees. There are also differences between races in natural history and biology. Some subspecies are more prone to swarming than others, some produce large numbers of young queens when swarming, others only a few. Tropical Honeybees frequently "abscond" or migrate, sometimes due to lack forage through drought or other causes, perhaps as a defence against predators. Heavy predation is also a likely cause of the vigorous defence reaction of some races, for example, the bees of tropical Africa. The bees of the warmer regions do not need to cluster as tightly as those confined to the nest through long, cold winters. Brood rearing is adapted to take maximum advantage of the local flora. Where bees of the same race have occupied different kinds of habitat, they have formed local strains which have accommodated themselves to the different conditions. Similarly, Honeybees of different races which have occupied similar habitats have evolved similar behavioural characters. Even the "dance language" by which Honeybees communicate information about the location of food sources may differ in detail between races as different races may be conditioned to foraging over different distances from the nest. (Professor Goetze described these differing dance patterns as “Honeybee dialects”.) The behavioural characters of the different races and strains, brood rearing pattern, foraging behaviour, clustering, etc., are fixed genetically, so that a colony cannot readily adapt itself when transferred to a different kind of environment. The Dark European Honeybee, *Apis mellifera mellifera*, is fairly uniform over its whole range, having had but a comparatively short time in which regional varieties could evolve, but even in this race differences can be observed between strains. In France, where the bee has been domiciled longest, there are distinct differences in brood rearing pattern between the *mellifera* bees of the Landes district in the Southwest, the bees of the Paris area and those of Corsica. The Landes bees are typical “heather bees”, conditioned to a principal nectar flow in late summer and early autumn. In the Parisarea there is no summer nectar flow and the bees show early spring brood activity. Exchange of colonies between the Landes and Paris resulted in poor performance in both cases. In Corsica the *mellifera* bees follow a Mediterranean pattern with little or no brood production in summer and a second peak in autumn. The effect of transferring bees to environments to which they are not adapted is graphically illustrated by experience in the tropic zone of South America. European Honeybees have been kept in Brazil for centuries, yet failed to establish a feral population in the country. When a few queens of a tropical race from Africa were introduced into the country, in a matter of a few years’ feral colonies of hybrids, “Africanised bees” had crossed the Amazon rain forest and moved North and South completely eliminating the European bees. The behavioural patterns which have evolved in the different races have ensured the survival of the various subspecies in their native habitats and some of these patterns may be repeated in different races. There is one race which, although of small economic importance, possesses an apparently unique biological character which renders it of great importance in the study of the genetics of Honeybees. In all other races, when a colony is rendered queenless, laying workers may appear which are capable of laying drone eggs only. In *A. m. capensis*, the Cape Bee, when a colony is deprived of its queen, a laying worker appears within a few days which, for a period, is able to lay predominantly diploid worker eggs. From these eggs true queens capable of being mated can be raised, re-establishing queen rightness in the colony. \Two attributes of Honeybees which have been essential to their evolution and biology are their clustering behaviour and, particularly in the case of the cavity-nesting species, their ability to cool the nest by evaporation of water collected outside. These attributes enable the colonies to achieve a marked degree of temperature regulation within the nest irrespective of the external temperature. The genus *Apis* was thus enabled to colonise a wide variety of environments, ranging from tropical to cool temperate. The *Meliponinae* which lack this capability are confined to tropical regions. Another behavioural character of Honeybees is the communication of information about food sources and the recruitment of foragers by “dance language”. The accurate dissemination of information concerning direction and distance of forage areas leads to efficient exploitation of food sources. At about 30 million years before present they appear to have developed social behaviour and structurally are virtually identical with modern honeybees. Among the extant members of the genus, the more ancient species make single, exposed combs, while the more recently-evolved species nest in cavities and have multiple combs, which greatly facilitated their domestication. Based on essentially morphological and behavioural analyses and the aid of different genetic techniques, the classification systematic of the true honeybees has obtained great achievements in the last two decades of the twentieth century. The tribe, Apini, consists of only one small monophyletic genus, *Apis* that comprises nine honeybee species. Reproductive isolation played a key role in this development. The different mating behaviours include : behavioural mating barriers (mating season, mating place, sexual signals, daily mating periods), copulatory barriers (size, genitalia, mating sign) and physiological barriers (sperm transfer, sperm storage) and postzygotic barriers (fertilisation, development, hybrids). Allopatric *A. mellifera* and allopatric populations of the other species had a uniform mating period during the afternoon hours. Sympatric honeybee species were separated mainly by different daily mating periods. The mating period differed between populations of the same species from different regions. The sequence of the mating periods, however, described from Sri Lanka, Thailand and Sabah (Borneo) followed the same pattern and showed a taxonomic and size correlation: the dwarf bees (*A. andreniformis* and/or *Apis florea*) occupied the first position shortly after noon. The next mating period was occupied by cavity-dwelling bees and at sunset, *A. dorsata* drones flew out for mating. In addition, in the honeybee species that have been studied, various non behavioural mating barriers have been demonstrated.

2.8 Africanized Bee

Widely known as the “killer bee”, Africanized bees are highly aggressive hybrids between European stock and the African subspecies *A. m. scutellata*; they are thus often called “Africanized bees”. Originating by accident in Brazil, they have spread to North America and constitute a pest in some regions. However, these strains do not overwinter well, and so are not often found in the colder, more Northern parts of North America. On the other hand, the original breeding experiment for which the African bees were brought to Brazil in the first place has continued (though not as intended): novel hybrid strains of domestic and re-domesticated Africanized bees combine high resilience to tropical conditions and good yields, and are popular among beekeepers in Brazil.

2.9 Stingless Bees

Stingless bees are amongst the longest evolved bees, and have been found preserved inside pieces of amber 80 million years old. Stingless bees developed before the continents drifted apart from each other. Unlike Apini, with only 11 species in the single genus *Apis*, stingless bees are a large and diverse taxon comprising some 60 genera, many of which are poorly known. The meliponine crown clade is inferred to be of late Gondwanan origin (approximately 80 mya), undergoing radiations in the Afro-tropical and Indo-Malayan/Australasian regions, approximately 50–60 mya. In the New World, major diversifications occurred approximately 30–40 mya. Dispersal vicariance based on the current phylogeny suggests that early stingless bees occurred throughout the range they currently occupy (Neotropical, Afrotropical, Indo-Malay/Australasia) or maybe the bees were initially restricted to the Afrotropical region followed by range-expansion to the Neotropical and Indo-Malay/Australasia regions. It is possible that as the continental plates moved and topographic barriers appeared, the ancestral fauna split into subgroups. The first major split occurred between the Old and New Worlds, followed by the isolation and diversification of the Afrotropical and the Indo-Malay/Australasian faunas. There is no support for the hypothesis of an original Eocene dispersal out of South America (Kerr and Maule 1964; Michener 1990) leading to the three basal clades. However, more recent dispersals of taxa near the tips of the phylogeny have occurred, such as those from Africa to Australasia (i.e. *Lisotrigona*, *Austroplebeia*). Therefore, they are present in all tropical parts of the world. It is estimated that there are more than 600 described (and many undescribed) species in approximately 61 genera, but new species are identified every year. Approximate numbers of species so far identified are 50 in Africa, 300 species in the Americas, 60 in Asia, 10 in Australia. Four species occur in Madagascar. However, several studies over the last two decades using morphological characters (Michener 1990; Camargo and Pedro 1992) and a single mitochondrial DNA gene fragment with limited (34 species) taxon sampling (Costa et al. 2003) resulted in phylogenies, although the patterns were inconsistent. Recently, Rasmussen and Cameron (2007) published a four-gene phylogeny of 64 meliponine taxa belonging to 22 of 25 Old World genera and 15 taxa belonging to 13 of 36 New World genera.

Stingless bees are very diverse in behaviour, but they are highly eusocial. They are of the tribe of Meliponini in the family Apidae, and closely related to the common Honeybees and found in most tropical or subtropical regions of the world. Stingless bees are not active all year round; they are less active in cooler weather. Unlike other eusocial bees, they do not sting but will defend by biting if their nest is disturbed. They live usually in nests in hollow trunks, tree branches, underground cavities, or rock crevices. Five hundred stingless bees' species are recorded and they are classified into five genera: *Melipona*, *Trigona*, *Meliponula*, *Dectylurina* and *Lestrimelitta* and some of them like *Trigona* and *Melipona* are the honey producing bees. Australian stingless (*Teragonula carbonaria*) bees produce less than 1 kg honey but it is prized as a medicine in many communities. The different species are diverse: their size ranges from 2 mm (e.g. the tiny sweet bees) to stingless bees slightly bigger than the European honeybee. The number of bees a colony can contain ranges from some few hundred to more than a hundred thousand bees. Meliponiculture is the management of bees in the genera *Melipona* and *Trigona*, and was traditionally important to Mayan culture in Mexico. Beekeepers would locate wild hives of these bees and bring them to their homes, where they provided the hive with a log in which to nest. The bees provided honey and pollination services for agricultural crops. Sadly, this beekeeping practice has become very rare.

This differs from species to species. Stingless bee species that produce honey belong to four main genus *Austroplebeia*, *Trigona*, *Melipona* and *Tetragonisca. Austroplebeia* are warm-loving species of stingless bee at the base of their thorax (between the head and the addomen) they have tiny cream coloured markings. It's hard to distinguish them apart from *T. carbonaria*, without looking inside at the different nest shape they have, but they often build a tunnel-like entrance into the hive, and make an intricate, lacy curtain of cerumen each night as a barrier across their doorway. One distinguishing behavioural difference is that unlike, Trigona that will crawl over the intruder, into eyes, ears, mouth etc. while the hive is being opened, Austroplebeia do not show this behaviour. *Trigona* build a hexagonal brood cell, in a flat layer spiraling outwards (horizontally). Austroplebeia do not build in a discernable regular pattern. The Austroplebeia queen has a light brown appearance, in contrast to the dark brown Trigona queen. With nectar available year round, a hive will rarely store more than 1 kg of honey. There are nine species described so far viz *Austroplebeia australis* (Friese 1898), *A cassiae* (Cockerell 1910), *A. cincta* (Mocsáry 1898), *Austroplebeia cockerelli* (Rayment 1930), *Austroplebeia essingtoni* (Cockerell 1905), *Austroplebeia ornata* (Rayment, 1932), *Austroplebeia percincta* (Cockerell 1929), *Austroplebeia symei* (Rayment 1932), *Austroplebeia websteri* (Rayment 1932). They like to nest in hollow trees and fight off small hive beetle invaders by sticking them down with resin and biting them species.

Trigona is the largest genus of stingless bees, formerly including many more subgenera than the present assemblage; many of these former subgenera have been elevated to generic status. There are approximately 150 species presently included in the genus, in 11 subgenera. They differ from those groups now excluded in only minor structural details, primarily of the hind leg. *Trigona* species occur throughout the Neotropical region, and also throughout the Indo-Australian region; as presently defined, no members of the genus occur in Africa. It is the largest genus of stingless bees, formerly including many more subgenera than the present assemblage; many of these former subgenera have been elevated to generic status. There are approximately 150 species presently included in the genus, in 11 subgenera. They differ from those groups now excluded in only minor structural details, primarily of the hind leg. It is a genus of the Meliponini tribe which is found extensively in tropical regions. It extends from Mexico to Argentina, India, Sri Lanka to Taiwan, the Solomon Islands, South Indonesia and New Guinea, but no members of the genus occur in Africa and 16 species of stingless bees were found in this area, namely. It extends from Mexico to Argentina, India, Sri Lanka to Taiwan, the Solomon Islands, South Indonesia and New Guinea, but no members of the genus occur in Africa. Many species exists in different parts of world viz., *Trigona barrocoloralensis*, *T. branneri*, *T. carbonaria*, *T. chanchamayoensis*, *T. collina*, *T. Iridipenis*, *T. fuscipennis*, *T. hockingsi*, *T. hyalinata*, *T. minangkabau*, *T. recursa*, *T. spinipes*. Two species (*Trigona binghami* and *Trigona minor*) are newly added to the list of 30 species recorded earlier by Schwarz (1939), and Michener and Boongird (2004) making a total of 32 stingless bees of *Trigona* species currently recorded under two genera

(*Trigona* and *Hypotrigona*.) in Thailand. Prominent among them were *Trigona apicalis* Smith, *T. melanoleuca* Cockerell, *T. atripes* Smith, *T. canifrons* Smith, *T. thoracica* Smith, *T. terminata* Smith, *T. ventralis* Smith, *T. flavibasis* Cockerell, *T. iridipennis*, *T. iridipennis*, *T. iridipennis*, *T. iridipennis*, *Hypotrigona scintillans*, *H. pendleburyi* and *H. klossi*. The diversity of *Trigona*. and their resin and gum collecting behaviour mostly depended on environmental factors. The bees prefer to collect resin and gum from 16 plant families including Anacardiceae, Dipterocarpaceae, Euphobiaceae, Hypericaceae, Meliaceae and Moraceae. During the rainy season they collected resin and gum all day, whilst during the dry season start from afternoon until late in the day. The *T. apicalis* collect resin and gum to make the largest number of propolis compared with the other bee species. *Trigona* (*Tetragona*) *iridipennis* is the most common dammar bee in the India. Other species were reported during 1940s and 1950s in general or from some parts of the country. Besides *Trigona iridipennis* that is common all over India, three other species occur in the Khasi hills, Meghalaya (Pugh 1947). Neto (1949) recorded a total of three species from India: *T.* (*Tetragona*) *iridipennis*, *T. ruficornis* and *T.* (*Lepidotrigona*) *arcifera. T.* (*T.*) *ruficornis* occurs in Haldwani, Uttar Pradesh (Neto 1949).

Species of *Trigona* live in hives, like European honeybees, and can be found in cavities in trees or underground. *Trigona* usually build their nests in hollow tree trunks or branches, and some in cavities in the ground or empty mice or parrot nests. Other species live in ants or termites' nests. Nests can sometimes be found in cavities in buildings. The various species prefer different cavity dimensions and most species have characteristic nesting sites. For example, the nests of *Trigona fulviventris* most often are found at the foot of a tree. In other species, the selection of nest sites is more variable. The entrance of the nest is most often very small, so that it can be protected against other bees, phorid flies and ants. The entrance can be a tubular structure, extending into the open air. Some have the opening pointing up – other openings are pointing downwards. The queen is the mother and the only bee in the hive that reproduces. The workers are her daughters, which do all the nest maintenance, bring home food, and raise their sisters. Males are only produced at a certain time of year, when new queens are produced. Males and new queens leave the nest to find mates, then the males die and the mated queens start their own hive. Nowadays, *Trigona* species are important pollinators for wild plants and agricultural crops in the tropics. They are key pollinators of macadamia, coconut, mango, and chayote. These bees also play a smaller role in pollination of coffee, avocados, and guava (to name just a few). The *Trigona* worker in the photo above is visiting an aloe flower (yep, the stuff in lotion) in Costa Rica. *Trigona* is the largest genus of stingless bees and have many subgenera. Commonly known as dammar bees, these are quite small in size and look like small mosquitoes or flies. They are distributed in tropics and sub-tropics, and even in temperate regions. They build their nests in dark enclosures like cavities in branches or trunks of trees, ant hills, termite tunnels in the ground, wall crevices or any abandoned receptacle like logs, pots and tins. The nests of *Trigona*, unlike those of *Apis*, are clusters of small uniform globular cells of wax. These pots are the cells in which the young are reared. The pots are closely stacked touching each other or separated each cell or cluster of cells being connected with others by girders or pillars of wax. Pollen and honey are stored in conspicuously large oval cells that are constructed close to the brood cell clusters or at their periphery quite apart from them. No clear separation of honey pots is found. Because of this the honey collected from dammar bees is rich in pollen that gets into it from pollen pots interspersed among the honey pots. Honey yields from dammar bees are very low; often a few grams to some 500 g. however, from forest areas in different parts of the country up to 2 kg of honey are collected from each nest of well grown colonies. Honeys of the dammar bee are dark amber in colour, show a highly positive polarization. The peculiar chemical composition and physical properties of the honey are attributed to the characteristic floral range the dammar bees have.

2.10 Melipona

Keeping stingless Melipona bees has been a tradition for Maya communities for centuries. Sadly, numbers of these special little bees are declining rapidly and the bees are now threatened with extinction – it's estimated that there has been a 93 % decrease in hives during the last 25 years. More than 500 species of Meliponinae are distributed in the tropical and subtropical regions of the world. These bees are native to the New World and were kept by ancient pre-Columbian cultures such as the Mayas and Nahuatls. Weaver *and* Weaver report evidence of meliponiculture, local rituals and ceremonies with a *Melipona* species. A rich figurative legacy can be found in the *Maya Codex* of Madrid, which has direct and indirect references to the life cycle of these bees. The *Melipona* species of stingless bees and most of the species. Also, much practical and academic work is been done about the best ways of keeping such bees, multiply their colonies and explore the honey they produce. Among many others, species like jandaíra (*Melipona subnitida*) and true-uruçu (*Melipona scutellaris*) in the northeast of the country, mandaçaia (*Melipona quadrifasciata*) and yellow uruçu (*Melipona rufiventris*) in the south-southeast, jupara (*Melipona compressipes manaosensis*) and straw-bee (*Scaptotrigona polistycta*) in the north and jataí (*Tetragonista angustula*) throughout the country are being increasingly kept by small, medium and large size producers, to the exploitation of honey or even to sell the colonies themselves, a profitable product as keeping stingless bees is an expanding activity. A single colony of species like mandaçaia and true-uruçu can be divided up to four times a year, and each of the new colonies obtained this way can be sold by about US$100.

In *Tetragonisca*, the entrance can be closed at night by a network of fine threads. The entrance tube can be so small, that only one bee can guard it, or it can be so wide that a whole group of soldier bees are necessary for its protection. Outside the entrance of *Tetragonisca angustula* there will even be a group of guard bees hovering around and able to catch intruders in flight. *Dactylurina staudingeri*, builds vertical double-sided combs. The brood chamber is surrounded by a protective wall made with wax and propolis – the involucrum.

2.11 African Races

Ngiru (a species of stingless bees): black and very small bee. Smaller than fly, follows about humans in seeking for water during the dry season. It makes nests only on natural tree trunks, which makes it very difficult to locate them; yielding only small quantity of honey but honey of excellent quality can be obtained.

Mbuo (a species of stingless bees): a bee that constructs subterranean nests. It is small in size, bears yellow hairs and shows black belt-like lines on body. The tribals in Andhra Pradesh assert that there are at least five different kinds of the dammar bees: *pedda* (big) *musuru*, *putta* (ant hill) *musuru*, *kaki* (crow) *musuru*, *cheema* (ant) *musuru* and *mala* (black) *musuru*. No detailed studies on their biology or honey production are so far reported. Neto (1949) emphasizing the need for further taxonomic work on the dammar bees reports of the remarks of H.S. Schwarz, a great specialist in the systematics of the dammar bees of the world, thus: "the number … (of the species of the dammar bees) … when the size of India is taken into consideration is notably small." In Malaysia 29 species of meliponinae (stingless bees) were recorded. India which has a larger geographic area and variety of vegetations and climates should have a larger number of species.

2.12 Honeybee Species and Commercial Beekeeping

Among the four commonly-recognized species of *Apis*, only *A. cerana* and *A. mellifera* are kept commercially by man. Behavioural limitations of the dwarf and giant honeybees, particularly their practice of open-air nesting, prevents 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. In many parts of the world, including several countries in Asia, commercial beekeeping depends on moving the honeybee colonies to places where forage is abundant at certain periods of the year. Such migratory beekeeping often calls for the colonies to be moved several times a year, over distances which may range from a few kilometers to several hundred kilometers from the home base. This approach is practicable only when the colonies are in movable-frame hives, which can he transported without danger to the hives or the colonies. From the practical standpoint, therefore, beekeeping can be a dependable agricultural occupation only when the beekeeper can determine and control the number of hives he owns.

Generally speaking, there are two possible approaches to the development of commercial beekeeping in Asia: the introduction of modern beekeeping with *A. mellifera* or the improvement of existing techniques for using *A. cerana*. Notwithstanding the difficulties involved in establishing new apiaries of the introduced colonies and in developing colony management techniques suitable to local conditions, *A. mellifera* colonies are generally more productive than those of *A. cerana* where forage is abundant, and the development of beekeeping with *A. mellifera* in Japan, the Republic of Korea, China and northern Thailand is based on this finding. On the other hand, where forage is available only marginally, colonies of *A. cerana* survive better and can produce with lower management inputs than colonies of *A. mellifera*. It is the absconding behaviour of most, if not all, tropical races of *A. cerana* that creates a major obstacle to the development of beekeeping with this bee in rural areas in southern Asia. Since this behaviour is apparently triggered, at least to some extent, by an unfavourable hive environment, proper colony management may be able to provide at least a partial solution to this problem.

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