2. BEE SPECIES DESCRIPTION

Bees kept by beekeepers are essentially wild animals and are not domesticated in the way of other livestock species. In some areas, for example, Europe and Africa, the bees used in beekeeping are indigenous species, and beekeepers are helping to maintain biodiversity by keeping healthy stocks of these bees. Until recently, it was true to say that any honeybees kept inside a hive by a beekeeper would be able to survive just as well living on their own in the wild. However, in recent years, man has spread honeybee pests and predators around the world, and this means that in some regions, the indigenous populations of honeybees have been killed and the only bees now surviving are those managed by beekeepers. For example, in Europe, honeybee colonies can only survive when beekeepers control levels of the (introduced from Asia) parasitic mite *Varroa destructor.*

Honey hunting, the plundering of wild nests of honeybees to obtain crops of honey and beeswax, is practised throughout the world, wherever wild nesting honeybee colonies are still abundant. However, for thousands of years it has been known that obtaining honey is made much easier and more convenient if bees are encouraged to nest inside a hive. Apiculture covers this whole, broad range of activities from the total plundering of wild bee nests for harvests of honey and beeswax, through to 'conventional' beekeeping, i.e. the keeping and management of a colony of bees inside a human-made beehive.

BEE SPECIES

In 1988, a bee preserved in amber from New Jersey was identified by US entomologists (Michener and Grimaldi, 1988). It was a worker, stingless bee of the species *Trigona prisca,* identical to bees of this species today. The amber dates from 80 million years ago, and we therefore know that bees of today were already evolved at that time. There are maybe around 30,000 bee species: about half have so far been recorded by entomologists. Most bees are solitary, which means that each female bee makes her own nest, lays a single egg and provides food for the single larva that develops. A few species show a high level of social development and live together in a permanent, large colony, headed by a single egg-laying queen. Although many species of bees collect nectar that they convert to honey and store as a food source, it is only these large colonies formed by social species that store appreciable quantities of honey. Only a very few species – maybe 30 or so – are exploited by humans for honey production.

These are the honeybees and stingless bees that have been, or are still, exploited by man to varying extents for their honey stores. Man has exploited them for thousands of years: until recent centuries, honey was the most common sweetening commodity. There are also a few, very rare instances of bumblebees being plundered for honey. Of course, the rest of the 30 000 bee species are also plant pollinators that are vital for the maintenance of biodiversity, and a few of these species are managed commercially for this purpose.

BEE TAXONOMY

The following is the current view of bee taxonomy according to Michener (2000): all bee species are classified within seven main families, and one of these is the family Apidae. Apidae has three subfamilies: Xylocopinae, Nomadinae and Apinae. The subfamily Apinae has nineteen tribes including Apini (honeybees), Meliponini (includes stingless bees), and Bombini (includes bumblebees). The tribe Meliponini are the stingless bees found in tropical and southern subtropical areas throughout the world (see Chapter 6).

The tribe Apini contains just one genus, *Apis* and these are the true honeybees. Like the Meliponini, they are social bees that establish permanent colonies. It is these bees' social behaviour, storing significant quantities of honey for the colony to survive dearth periods, which means they have been, and are still today exploited by human societies for their honey stores.

HONEYBEES

There are very few species of honeybees. Most beekeeping textbooks still declare that there are just four species: *Apis mellifera, Apis cerana, Apis florea and Apis dorsata* (Ruttner, 1988). The honeybee is one of the most studied of all animals, other than man, yet this research has been almost entirely on the European honeybee *Apis mellifera*. Amazingly however, only within the past 15 years or so a number of 'new' honeybee species have been recorded for science, and Michener names eleven species in the genus *Apis*. They are:

Apis andreniformis	*Apis koschevnikovi*
Apis binghami	*Apis laboriosa*
Apis breviligula	*Apis mellifera*
Apis cerana	*Apis nigrocincta*
Apis dorsata	*Apis nuluensis*
Apis florea	

These eleven species of honeybees nest in one of two different ways, and this nesting behaviour determines whether or not the bees will tolerate being kept inside a man-made hive. Some of the species make nests consisting of a series of parallel combs, other species nest on just one, single comb. The species that build a series of parallel combs usually nest inside cavities, and this behaviour enables them to nest inside man-made containers and therefore opens up possibilities for the keeping and management of these bees inside hives.

TABLE 2
Species of honeybees: type of nest

Honeybee species whose nests consist of multiple combs (cavity nesting honeybees)	**Honeybee species whose nests are single combs**
Apis cerana *Apis koschevnikovi* *Apis mellifera* *Apis nigrocincta* *Apis nuluensis*	*Apis andreniformis* *Apis binghami* *Apis breviligula* *Apis dorsata* *Apis florea* *Apis laboriosa*

The species that build single combs usually nest in the open. They cannot be kept in hives and the single comb behaviour does not lend itself to beekeeping management practices, although the honey and other products of these species are harvested by some societies.

Honeybee species whose nests consist of multiple combs

Apis mellifera

Other names for *Apis mellifera* are the hive bee, the European bee, the Western hive bee, and the occidental honeybee. Most standard beekeeping texts relate only to *Apis mellifera* (although this is not always stated).

Apis mellifera is indigenous to Africa, Europe and the Middle East. It has been introduced to the Americas, Australasia and much of the rest of the world. Today, Argentina, China and Mexico have the largest honey industries in the world, and all are based on the introduced *Apis mellifera* honeybee.

There are many different races of *Apis mellifera*, some tropical, others temperate. The Africanised 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. Generally, *Apis mellifera* are regarded as the medium-sized honeybees, against which other species are judged as "large" or "small".

Apis mellifera usually builds its nest inside an enclosed space. The nest consists of a series of parallel combs, and there are typically 30 000-100 000 honeybees in one colony.

Apis cerana
Another name used for *Apis cerana* is the Asian hive bee, and it is sometimes incorrectly named *Apis indica*. *Apis cerana* is indigenous to Asia between Afghanistan and Japan, and occur from Russia and China in the north to southern Indonesia. *Apis cerana* has been introduced recently to Papua New Guinea. *Apis cerana* builds a nest consisting of a series of parallel combs, similar in style to *Apis mellifera*, and builds its nest within a cavity. As with *Apis mellifera*, *Apis cerana* occurs over a huge geographical area, and it varies in size throughout its range: tropical races are smaller, with smaller colonies. There are many different races of *Apis cerana*, as could be expected from the wide range of habitats it occupies from temperate mountain regions to tropical islands.

Apis koschevnikovi
This honeybee species has been identified only in Sabah, Malaysia in Northern Borneo. Locally known as the red bee, this species was named for a short period *Apis vechti*. The individual bees are slightly larger than *Apis cerana* found in the same locality, but otherwise the nests of these bees are similar in size and construction. They are known locally as red bees due to their reddish hue when clustering.

Apis nigrocincta **and** ***Apis nuluensis***
Apis nigrocincta has been identified only in Sulawesi in Indonesia (Otis, 1996), and *Apis nuluensis* only in Borneo. Their nesting behaviour is similar to *Apis cerana* and *Apis koschevnikovi,* described above.

Honeybee species whose nests are single combs

Apis andreniformis **and** ***Apis florea***
These are very small-sized species of bees, and their single comb nests are small too: often no larger than 150-200 cm wide. Other names include the little honeybee, and sometimes (wrongly) the dwarf honeybee. These bee species build a single-comb nest, usually fairly low down in bushes, or in the open, suspended from a branch or (for *Apis florea*) rock surface. *Apis andreniformis* has been identified in South East Asia, Borneo, the Philippines and the southern Chinese peninsula, while *Apis florea* is indigenous from Oman spreading southeast through Asia as far as some of the islands of Indonesia and the Philippines. In 1985, it was identified in Sudan and lately reported in Iraq. However, it is only recently that *Apis andreniformis* has been recognised, and some records for *Apis florea* may prove to be for *Apis andreniformis.*

Apis dorsata
Other names for *Apis dorsata* are the rock bee, the giant honeybee, or the cliff bee. On the western edge of its distribution, *Apis dorsata* is found only as far as Afghanistan but its southeast occurrence extends east of Bali. Its northern distribution is limited by the Himalayas. There is morphometric and genetic evidence for many different subspecies of *Apis dorsata* that may eventually be proved separate species. *Apis dorsata* bees are large, and their nests consist of single large combs suspended from a branch, cliff face or building.

Apis binghami **and** ***Apis breviligula***
Apis binghami occurs in Sulawesi in Indonesia, and *Apis breviligula* occurs in the Philippines. Maa (1953) first recorded them as separate species, although subsequent authors ignored this and regarded them all as the same species, *Apis dorsata.* Recently, with genetic analysis allowing increasing understanding of the great diversity with the species *Apis dorsata,* these two are once again regarded as separate species.

Apis laboriosa
Apis laboriosa are the largest of the honeybees. They are found in the Himalayas (Nepal, Bhutan, and China) at higher altitudes than *Apis dorsata*. *Apis laboriosa* nests are similar to those of *Apis dorsata*, but *Apis laboriosa* colonies are usually found together in clusters, with sometimes up to 100 combs suspended from a cliff face very near to one another, although *Apis dorsata* may also be found nesting in this way.

BEE SPECIES USED FOR APICULTURE

The honeybees most widely used for beekeeping are European races of *Apis mellifera*, the species of honeybee also indigenous to Africa and the Middle East. No species of honeybee occurs naturally in the Americas, Australia, New Zealand or Pacific islands: European bees have been introduced to these regions during the last four centuries. Over the last 30 years, European bees have been also introduced to most countries of Asia. In industrialized countries, all beekeeping technology has been developed for use with European honeybees, and most beekeeping and research literature relate only to this bee.

Other honeybee species are also exploited by humans for their honey. Although the cavity nesting species can be kept in hives, and managed according to beekeeping practices, in some countries, wild nesting colonies of these bees are still sought by honey hunters.

The single-comb nesting species cannot be kept inside hives, so it is only wild-nesting colonies that are exploited by honey hunting. There are of course exceptions: *Apis florea* is managed by beekeepers in Oman (Dutton, 1982), and in several countries in Asia, *Apis dorsata* is managed to some extent, for example in India (Mahindre, 2004) and Vietnam (Mulder *et al*, 2001). There is more information on this in Chapter 5.

DIFFERENCES BETWEEN TROPICAL AND TEMPERATE ZONE RACES OF HONEYBEES

European races of *Apis mellifera* have evolved in temperate climates with long, cold winters when little or nothing is in flower. They store honey to serve as a food supply to survive these times of dearth when there is little or no food available. Apart from swarming (the colony's reproduction), they remain in their hive because they are unlikely to survive if they leave in search of a new nesting place. By comparison, all tropical races and species of honeybees are far more likely to abandon their nest or hive if disturbed, because in the tropics they have a reasonable chance of survival. In some areas, tropical honeybee colonies migrate seasonally. These are crucial factors making the management of tropical honeybees different from the management of temperate zone honeybees.

TABLE 3
Species of honeybees: indigenous distribution

Region	Indigenous honeybee species	Honeybee species introduced
AFRICA	*Apis mellifera*	*Apis florea* introduced to Sudan, 1985
ASIA*	*Apis andreniformis* *Apis binghami* *Apis breviligula* *Apis cerana* *Apis dorsata* *Apis florea* *Apis laboriosa* *Apis koschevnikovi* *Apis nigrocincta* *Apis nuluensis*	*Apis mellifera*
AUSTRALASIA	No indigenous honeybees	*Apis mellifera* *Apis cerana* has been introduced to Papua New Guinea
EUROPE	*Apis mellifera*	
MIDDLE EAST	*Apis mellifera* *Apis florea*	
THE AMERICAS	No indigenous honeybees	*Apis mellifera*

* Not all of these species are indigenous to every country of Asia.

AFRICA

Apis mellifera honeybees are indigenous to Africa. There are many different races of African bees; see Ruttner (1998) for more information. In South Africa bees are of the race *Apis mellifera capensis*, a race of bee with unique biology and behaviour (see below). Tropical races of *Apis mellifera* are slightly smaller than the European races of *Apis mellifera* and they have different biology and behaviour: they are readily alerted to fly off the comb and to defend themselves. In many African countries, local beekeeping methods are used, with log, bark, basket or clay hives placed in trees. Where the behaviour of bees is to swarm and migrate, it can be a good beekeeping strategy to use a large number of low cost hives. This means that the beekeeper can afford to have a large number of hives and accept that some of them will be unoccupied at some periods. Throughout Africa honey hunting from wild nests is carried out wherever sufficient natural resources remain. Stingless bees are also present throughout tropical and southern sub-tropical Africa.

BOX 3
Apis mellifera capensis

Apis mellifera capensis, known as the Cape honeybee, is a race of *Apis mellifera* whose natural distribution is confined to the southern tip of Africa, and which has a unique, highly complex biology that has only recently been understood. The unique feature of *Apis mellifera capensis* is that worker bees, without any mating taking place, are able to lay diploid, female eggs. This biology is not known in any other honeybee species or race, where the usual 'rule' is that worker bees lay only haploid, male eggs that develop into drones.

The recent (1990) movement by beekeepers of these bees from southern to northern South Africa caused the widespread death of African honeybee (*Apis mellifera scutellata*) colonies. The *Apis mellifera capensis* workers enter the *Apis mellifera scutellata* colonies, and this soon leads to colony break down and death. It seems that the eggs laid by the *Apis mellifera capensis* bees evade being killed by other worker bees, as would normally happen, and ultimately the colony breaks down. The spread of these *Apis mellifera capensis* bees in South Africa, together with the recent introduction of *Varroa* mites, has severely curtailed beekeeping in South Africa and these issues may eventually affect on bees and beekeeping throughout Africa.

ASIA

At least eight honeybee species, varying in biology and behaviour, occur naturally within Asia. Some of these bee species build nests consisting of single combs, in trees, bushes, or in cliffs, and a great variety of methods have been developed by human societies for their exploitation.

For example, the giant honeybee, *Apis dorsata*, suspends its large combs (often one metre in diameter) from tree branches and overhanging ledges on rocks and buildings. Man obtains honey crops from this species by plundering their colonies, and this activity is known as honey hunting. Throughout Asia, from Gurung tribesmen in the Himalayas, to mangrove-dwellers in the Sunderbans of Bangladesh, the rain-forest people in Malaysia, people living in the river deltas of southern Vietnam, and indeed, wherever the giant honeybee is present, honey hunters have their own customs for exploiting these bees (see Chapter 5).

Apis cerana is known as the Asian hive bee because like European *Apis mellifera*, it can be kept and managed inside a hive. Moveable frame hives and movable comb hives (top-bar hives) have therefore been developed for *Apis cerana* and the other cavity nesting hive bees.

Stingless bees are also present throughout tropical and southern sub-tropical Asia.

European *Apis mellifera* have been introduced to most of Asia as shown in Table 4, and this exotic species may now be the predominant honeybee species present in China, Japan and Thailand, and other countries of Asia.

TABLE 4
Numbers of *Apis mellifera* colonies in Asia

	1984	1994	2004		1984	1994	2004
Afghanistan	20 000	?		**Japan**	284 000	225 000	
Bangladesh	0	?		**Malaysia**	<500	present	
Bhutan	0	50		**Nepal**	2	1 000+	
Brunei	?	0		**Pakistan**	1 000	14 000	
Burma	2 000	2 000+	5 000	**Philippines**	2 000	6 000	
Cambodia	?	?		**Singapore**	?	present	
China	4 000 000	6 800 000		**South Korea**	280 000	300 000	790 000
Hong Kong	?	100+		**Sri Lanka**	4	not permitted	
India	3 000	80 000		**Thailand**	30 000	100 000	300 000
Indonesia	1 000	31 000		**Vietnam**	16 000	70 000	470 000
Laos	?	present					

AUSTRALASIA AND PACIFIC OCEAN ISLANDS

There are no honeybees indigenous to this region, although there are indigenous species of stingless bees that have been harvested traditionally. European races of *Apis mellifera* have been widely introduced and are used for beekeeping. Recently *Apis cerana* has been introduced to Papua New Guinea.

CARIBBEAN

Although indigenous stingless bees are present, no honeybees are naturally occurring in these islands. *Apis mellifera* of European origin have been introduced to most of them and beekeeping industries have developed using European-style beekeeping methods. With the rapid spread of honeybee diseases around the world, it is increasingly important that these islands endeavour to maintain stocks of disease-free bees. Caribbean beekeepers must watch for Africanised bees that have already arrived in Trinidad.

EUROPE

Apis mellifera is the honeybee indigenous to Europe, and there are many different races of the bees. See Ruttner (1988) for a detailed account. During the 20th century, bees were moved by beekeepers from one area to another and many hybrids were created. Today there is more interest to identify and preserve the original races of bees that are now appreciated to be the bees best suited for their own areas. For example, Slovenia is home to the indigenous Carniolan bee *Apis mellifera carnica*, known as “sivka” meaning “grizzly” because of the bright grey hair along the edges of its abdomen, and admired by beekeepers for its characteristic gentleness and diligence. Because of this behaviour, people started to keep it in hives close to home. News of the gentle character of this grey bee soon spread to other nations and by the end of the 19th century; there was the beginning of a lively trade in live bees and swarms, later to include Carniolan queens. Until the beginning of World War I, specialized Slovene merchants exported tens of thousands of bee colonies and, in many places; these completely replaced the indigenous dark bee. Today, honeybee queen breeders, who sell approximately 40 000 queens, mostly to the countries of Central and Western Europe, with exports increasing annually, are continuing their work. Slovenia joined the EU in May 2004, and the beekeeping sector was well prepared, with legislation for an “Authentic Carniolan Trademark” for the marketing of indigenous Carniolan genetic material and a well-organised reserve area for the indigenous bees.

Apis mellifera carnica is also kept fruitfully in neighbouring Austria and Croatia, as well as elsewhere in Central and Eastern Europe. This bee species is well adapted to the climate and foraging conditions of these countries. It tolerates local conditions: cold, snowy winters, frequent rainy and windy summers and makes good use of available forage. One of its beneficial characteristics is discovering and collecting honeydew from spruce and fir trees. Almost 60 percent of Slovenia retains its forest cover, with mixed coniferous and deciduous forests offering rich forage for bees. The most important honey-producing trees are fir and spruce, followed by sweet chestnut, lime, sycamore and wild cherry.

BOX 4
Save indigenous bees in Europe[1]

One of the last remaining populations of the European honeybee *Apis mellifera mellifera* is threatened. These are the Black Bees on the Danish Island of Læsø, an isolated island that lies west of Sweden in the Kettegat Sea. In 1992 Denmark signed the Rio Convention on Biological Diversity, and the law was passed for Læsø Island to become a protected area where only beekeeping with the Black Bees is allowed. After this, beekeepers who kept other bees claimed compensation, although this claim was later dropped. They also took their case to the European Court in Luxemburg, but were unsuccessful. The Court ruled that the Preservation Order on the Læsø Black Bee was a requirement of The Danish Government, and that no other race of bees should be allowed on to the Island. Today on Læsø there are about 30 beekeepers using the Black Bees, and just a few who continue to fight the ban and illegally use other bees, and even import bees. This has lead to the recent introduction of *Varroa* and *Acarapis* mites.
Ironically, it was only in September 2004 that SICCAM (The International Organization on the preservation of the Northern European Black Bee) held its biannual conference on Læsø, to focus attention on the need to protect this special bee population. SICCAM passed a resolution calling for this unique population of bees to receive the protection it needs.
Now, however, the Danish Minister of Agriculture and Food, Hans Christian Schmidt has decided that it is in the interests of human liberty for the few, vocal, beekeepers who request it, to be allowed to take in other races of bees to the Island, and that only a small part of the Island will be a protected area for the Black Bees. The island of Læsø is only 25 km long; therefore, as every beekeeper will understand, it is not possible to keep the populations of bees separate.
Meanwhile, the Danish Beekeepers Federation has fought hard to protect the black bees, even though its own government subsidy is at stake.
The majority of beekeepers in Denmark want the Black Bees on Læsø to be protected. This is a precious resource, not just for Denmark but also in world terms.

THE AMERICAS

There are no honeybees indigenous to the Americas. Instead, their ecological niche was filled by the many different species of stingless bees, which were, and still are in some areas, exploited for their honey that is especially valued for its medicinal properties. Knowing nothing of these indigenous bees, European settlers long ago took with them European bees, and an industry developed based on this bee. In 1956, some tropical, African *Apis mellifera* bees were introduced into Brazil. These bees survived far more successfully in tropical Brazil than their European *Apis mellifera* predecessors. These 'Africanised' bees (dubbed 'killer bees' by the media) have spread through tropical parts of South and Central America, and are now in southern USA. In Brazil and neighbouring countries, beekeepers developed new management methods and now make excellent livelihoods with these bees.

THE NEAR EAST

Apis mellifera is also the indigenous bee of the Near East, and as everywhere, there are indigenous races of *Apis mellifera* that have their own characteristics highly suited to local conditions. Middle Eastern races include *Apis mellifera syriaca* and *Apis mellifera yemenitica*, desert races that survive hot, arid conditions. *Apis florea* is also present in some countries of the Middle East, and its honey is highly prized, often changing hands at over US$100 per kilogram.

PROBLEMS WITH THE INTRODUCTION OF EXOTIC BEE SPECIES AND RACES

As far as beekeepers are concerned, throughout the 20thcentury the other man's grass was always greener – bees in other countries were viewed as more prolific, gentler, more disease resistant, less prone to swarming, more yellow, blacker. Indeed many beekeepers still think this way, and this has led

[1] Bradbear, 2005.

to the disasters of recent years, when races of bees, or diseases and parasites of honeybees have been spread around the world with serious consequences for the beekeeping industries, and indigenous populations of bees, in many countries. This has been caused entirely by the movement of honeybee colonies by man.

For example, the mite *Varroa destructor* is a 'natural' parasite of Asian honeybees that survive in the presence of the mite. However, when particular races of the mite are introduced to European *Apis mellifera* honeybees (the bee used for beekeeping in most industrialized countries), the whole colony will be killed unless action is taken by the beekeeper. These mites have now been introduced to many beekeeping countries and, for example, most populations of wild honeybees throughout Europe have been killed during the last 20 years or so. Mites become resistant to medicines developed for their treatment, and research is underway in many countries to find better, integrated control methods, or resistant strains of bees.

Recently another predator, the small hive beetle, *Aethina tumida*, has been spread from Africa (where it is a relatively harmless pest for bees) to honeybee colonies in the USA, where it leads to destruction of European honeybee colonies.

The introduction of African bees to south America was initially viewed as a disaster, as the introduced African bees survived very well in their new habitat, and their population quickly expanded through south and central America, replacing existing populations of European honeybees, there were less well suited to the tropical environment. However, today some view this amazing, dramatic event in a more sympathetic light – as beekeeping industries have learned to adapt to the African bees. The Brazilian scientist who introduced the African bees, Professor Warwick Kerr, has with hindsight, expressed the opinion that it would have been wiser to have focussed efforts on the Americas' indigenous, stingless bees (Bradbear, 1993).

Honeybees and used beekeeping equipment must never be moved from one area to another without expert consideration of the consequences. Just a very few regions remain without introduced honeybee diseases, and these are mainly in developing countries. It will be highly beneficial for these countries if they can retain their stocks of disease-free honeybees: they may in the future be able to market their disease free stocks, or export disease free queen bees, and it makes possibilities for organic honey and beeswax production cheaper and easier.

THE CONSERVATION OF INDIGENOUS HONEYBEE SPECIES AND RACES

Globalisation is taking place in beekeeping, as in every other sector. Beekeeping with European races of honeybees, plus all associated technology, is being spread around the world. The consequences of competition between introduced (exotic) honeybees and indigenous honeybee species and races are unknown.

3. THE IMPORTANCE OF BEES IN NATURE

BEES AS PART OF ECOSYSTEMS

Pollinators strongly influence ecological relationships, ecosystem conservation and stability, genetic variation in the plant community, floral diversity, specialization and evolution. Bees play an important, but little recognized role in most terrestrial ecosystems where there is green vegetation cover for at least 3 to 4 months each year. In tropical forests, savannah woodlands, mangrove, and in temperate deciduous forests, many species of plants and animals would not survive if bees were missing. This is because the production of seeds, nuts, berries and fruits are highly dependent on insect pollination, and among the pollinating insects, bees are the major pollinators. In rain forests, especially in high mountain forests where it is too cold for most bees, other pollinators like bats and birds play a greater role in plant pollination. In farmed areas, bees are needed for the pollination of many cultivated crops (see Chapter 7), and for maintaining biodiversity in 'islands' of non-cultivated areas. The main role of bees in the different ecosystems is their pollination work. Other animal species are connected with bees: either because they eat the brood or honey, pollen or wax, because they are parasitic to the bees, or simply because they live within the bees nest.

WHAT IS POLLINATION?

Pollination is transfer of pollen from the anther (the male part of the flower) to the stigma (the female part of the flower). Some plants can pollinate themselves: in this case, the pollen passes from the anther to the stigma inside the same flower, and this is called *self-pollination*. Other plants need pollen to be transferred between different flowers or different individuals of the plant. This is *cross-pollination*. Many plants can be pollinated both ways. Plants can be pollinated by wind or animals.

Some plants have only one method for pollination, others use a combination. The knowledge of pollination by animal pollination (*Zoophily*) in the tropics is still little known, and much work and research have to be done in this area. Some general rules can be used to detect whether a plant is pollinated by bees, flies, beetles, wasps, butterflies, moths, thrips, birds, bats, marsupials, slugs or rodents. Flowers pollinated by bees most often bloom in daytime, they can have different colours, but seldom red. The scent of daytime bee pollinated flowers tends to be less strong than that of night-pollinated flowers, often pollinated by bats or moths. Honeybee pollinated flowers have nectar tubes not more than 2 cm long. They have nectar guides (patterns to direct the bee towards the nectary) and often a landing place for bees. Bees are especially attracted to white, blue and yellow flowers. Plants pollinated by insects are called "entomophilous", and insects are generally the most important pollinators.

THE POLLINATION WORK OF BEES

If we look at the many colourful and different looking flowers, we should not forget that they have developed as an adaptation for the bees and other pollinators, and not to please humans! Bees and most flowering plants have developed a complex interdependence during millions of years. An estimated 80 percent of flowering plants are entomophilous i.e. depending more or less on insect pollination to be able to reproduce, and it is estimated that half of the pollinators of tropical plants are bees.

The efficiency of honeybees is due to their great numbers, their physique and their behaviour of foraging on only one plant species at one time. The bees have to find their food in flowers. The food can be nectar or pollen. Nectar is produced to attract the bees. Pollen is also attracting the bees, but it has another function too: it is produced to ensure the next generation of plants. Bee pollinated flowers have evolved in such a way that a visiting bee has to brush against the flower's anthers bearing pollen, or there may be a special mechanism to release the anthers to spring up or down to cover the bee with pollen. Compared with other insects, bees are extremely hairy. Each hair has a branched structure that makes it highly effective at catching pollen.

While flying to the next flower, the honeybee will brush herself and move many of the pollen grains, to arrange them in the pollen baskets made of stiff hairs on her hind legs. Some pollen grains are so dry that they cannot be formed into a clump. To prevent the pollen falling off during flight, the bee will regurgitate some nectar and mix it with the pollen. This gives the sweet taste when eating pollen balls collected by bees. It also makes the pollen a little darker so that it can be difficult to see from which plants it comes. Some bees do not have pollen baskets – they transport the pollen in the hair on their abdomen (e.g. *Osmia* bees and leaf cutter bees). When the honeybee with pollen is landing in the next flower, there will be pollen enough left on the bees' body hairs to pollinate the new flower, by delivering some grains to the flower's stigma. Now pollination has taken place. To create a seed, the pollen grain has to grow a small tube inside the stigma to the ovary of the flower. Then a male gamete can travel through the tube, fertilize the egg cell and start development of the fertile seed. Now the fertilization has taken place.

Some plants need several successful visits from bees to ensure that all the flower's eggs are fertilized. For example, some varieties of strawberry need about 20 pollen grains – requiring visits by several bees, an apple flower may need four or five bee visits to receive enough pollen grains for complete fertilisation. If the fertilization is inadequate because of lack of bees, not all seeds will develop, and the shape of the fruit will be poor and small. Fertilization is the beginning of a new seed, which perhaps will grow and develop into a new plant. The new plant will bloom, provide the bees with food, be pollinated, and be fertilized, and in this way, the story continues.

The forager bee returns to the honeybee colony with her pollen loads, which are placed in the nest in areas of comb close to the brood.

Bees have to learn where in a flower the nectar is to be found. To guide the bees, many plants have *bee-tracks,* which are lines of colour leading the bee towards the nectar. These can sometimes be seen by humans, but some are in the ultra-violet part of the spectrum and visible to bees, but not humans. In this way, the plant also guides the visiting bee to pass the anthers or stigma in the right way. Bees have no problems in finding the nectar in flat, open flowers, but in flowers that are more complex, they have to learn it by trial and error. After some visits in the same type of flower, the bee has learned where the nectar is, and learns this for the next visit. Pollen is the protein food for bees. Without pollen, the young nurse bees cannot produce bee milk or royal jelly to feed the queen and brood. If no pollen is available to the colony, egg laying by the queen will stop.

Usually a honeybee can visit between 50-1000 flowers in one trip, which takes between 30 minutes to four hours. In Europe, a bee can make between seven and 14 trips a day. A colony with 25,000 forager bees, each making 10 trips a day, is able to pollinate 250 million flowers.

The ability of the honeybee to communicate to other bees in the colony where to go for collecting more pollen and nectar is very important for their efficiency as pollinators. When a scout bee has found a good nectar or pollen source, she will return to the colony and communicate to other bees where they can find the same food. This is done with a special dance indicating the distance, quality, and direction from the nest. Flowers closer than around 200 metres are just announced with the waggle dance without indicating any direction. Chapter 6 describes how these stingless bees are guided to the flowers.

When bees begin foraging for pollen and/or nectar, they will visit the same species of flowers and work there as long as plenty of nectar or pollen can be found. For example, if a honeybee starts collecting in an *Acacia* tree, she will fly from *Acacia* flower to *Acacia* flower, and not behave as many other insects do, visiting different species of plants within the same trip without any great pollination effect. This behaviour of bees is called *foraging constancy*.

Some flowers are open and with nectar all day and night, but others are open only for a few hours in the morning, afternoon or night. The single worker bee learns and remembers what time the different flowers are worth visiting. One bee can remember the opening time for up to seven different types of flowers. The honeybees are pollinating a great number of different plant species, and they do it effectively. Some solitary bee species are much more specialized for pollinating specific plant species.

SPECIALIZED POLLINATION

Some species of plants and bees have developed a close interdependence in connection with pollination. Such a mutual adaptation and interdependence between a plant and pollinator is a result of a long and intimate co-evolutionary relationship. The pollinating bees of the Brazil nut tree *Bertholletia excelsa* is an illustrative example of such a relationship and its economic importance.

The Brazil nut tree grows wild in the Amazon Forest. Brazil nuts are one of the economically most important wild products growing trees in the area, with more than 50 000 tonnes of the nuts exported from Brazil every year. The Brazil nut trees cannot be grown in plantations, because they need to be pollinated by one special bee species, the small shining *Euglossa* bee. This bee is dependent on the presence of an orchid species that is found only in the rain forest. They are also the only pollinators for a number of orchids in the forest. In some species of *Euglossa,* the male bee collects some scented material from the flower, which they distribute to attract other males – who do the same and multiply the effect with a scented cloud, in the end so strong, that it attracts female bees so that mating can take place. During the collection of the scented material, male bees transfer pollen from orchid to orchid and pollination takes place. The female *Euglossa* bees live from nectar from the Brazil nut tree and pollinate it. This means that without the orchids, there would be no *Euglossa* bees and no Brazil nut trees, and none of the many other plants, insects and animals associated with that tree – including the people whose livelihoods include collection and sale of the Brazil nuts.

Studies in the Amazon forest have shown that many *Euglossa* bees do not cross open areas. That means that great parts of forest lose its pollinators when the forest is cut, and open parcels of land are created between remaining forest islands.

This example is only one of many important specialized interrelations between bees and trees. In spite of this, the bees perhaps play a minor role as pollinators in the rain forest compared to their role in temperate forests, monsoon forests and savannah woodland. In tropical rain forests, many trees are pollinated by birds, bats and insects other than bees. Animal pollination is of greatest importance, because there is no wind between the trees and because the distance between trees of the same species may often be great. In that way, it is most convenient for the trees to use animals as pollination vectors. In tropical forest, there may be rather few flowering plants on the ground because of the trees' shade.

In European deciduous forests, the forest floor can be totally covered by flowering plants in springtime, before the trees produce their leaves. These plants often need fast pollination from a great number of honeybees. Not many other insects are present in high numbers in early spring.

In Denmark, it is seen by forestry people that the presence of bees in forest areas helps to protect the newly planted trees from being eaten or spoiled from gnawing by roe deer, compared to other plantations with no bees. The reason is because bees secure a better pollination and seed production of so many other plants, which the roe dear can forage on instead of the tree seedlings. By pollinating trees, bushes and herbaceous plants, the bees are important for the food production of all the other animals and birds in the forest ecosystem dependent on it for food berries, seeds and fruits.

BEES ARE GOOD FOR TREES AND TREES ARE GOOD FOR BEES

Bees and trees belong together. The honeybees and stingless bees have originally developed in forest biotopes. Given the choice, wild honeybees chose nesting places in trees rather than in an open landscape. Most often the honeybees prefer to build their combs or nests high in trees instead of close to the ground, but bees nests can be found everywhere in a tree. In savannah areas with bushfires in the dry season, a high nesting place is an advantage. When beekeeping is present in a forest, the beekeepers will be interested in protection of the forests and especially the tall trees preferred by the bees. When enough bees are present in a forest, they provide a better pollination that leads to improved regeneration of trees and conservation of the forest's biodiversity.

BEES AND BIODIVERSITY

Without bees there would be no flowering plants, and without flowering plants there would be no bees. Without bees biodiversity would not be so great. Biodiversity is measured as the number of different plant and animal species found in a certain unit area. Biodiversity is highest in tropical forest areas and lowest in the Arctic. High biodiversity is related to the high age of the ecosystem, and a stable environment. A stable environment creates the possibility of development of specialization and use of narrow ecological niches. The explanation of the high biodiversity in tropical forests can be as the species' efforts to avoid attack by diseases and pests. Both can be much more serious in a tropical forest biome with a constant supply of water, and a hot and stable temperature. The high diversity with its high specialization in pollination relationships can also be a danger for the forest. The specialist pollinator must have access to food all year round. Many of the smaller trees flower all year round or nearly all year, but the larger trees have blooming seasons. Some flower every year, others every third or fifth year, where all trees from the same species bloom at the same period and maybe even at the same hours. If the specialized bees loose their stable resources by tree cutting, they will not be there when the bigger trees require their pollination service.

The reproduction of plants is simplest as vegetative reproduction – a new tree could just come from a root shoot. The new tree would then be genetically identical with the mother tree. Vegetative reproduction alone would be no problem if the environment were stable, but most environments are not stable over time, they change. It can be climatic changes, new diseases or pests. To be able to adapt to environmental changes there need to be genetically different plants. In that way there will always be some plants, which are better adapted than others because of special genetic constitutions. The only way to constantly mix the genes for the plants is by cross-pollination, where pollen from one plant is transported by bees to another so that the offspring become genetically different. In that way, there is a greater chance for at least some of the offspring to survive in the competition of life. In this we find the bees as one of the most important factors.